INVESTIGATING THE RELATIONSHIPS AMONG NEIGHBORHOOD FACTORS AND ASTHMA CONTROL IN AFRICAN AMERICAN CHILDREN

By

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Abstract

Racial and socioeconomic disparities in childhood asthma have been partially attributed to differential neighborhood exposures associated with poverty. Greenspace, or land with grass, trees or other vegetation, is a modifiable neighborhood exposure that may improve asthma control. However, living in unsafe neighborhoods may limit the potential benefits of greenspace. This study examined associations among neighborhood greenspace, neighborhood safety, and asthma control in a sample of low-income, predominantly African American children (age 3-12) diagnosed with uncontrolled asthma in Baltimore (n=196).

Primary hypotheses were: 1) more neighborhood greenspace would be associated with better asthma control; 2) lower neighborhood safety (i.e., violent crime victimization rate, perceived neighborhood safety) would be associated with poorer asthma control; and 3) neighborhood safety would moderate the relationship between greenspace and level of asthma control. Multivariable logistic regression models were used to test study hypotheses, controlling for demographic, social, and environmental risk factors.

Most of the sample children were African American (95%), male (65%), insured by Medicaid (95%), exposed to secondhand smoke (59%), and diagnosed with very poorly controlled asthma (55%). Results did not support hypotheses 1, 2, or 3. Limited sample size and variability may have influenced these results. Additional analyses demonstrated significant interactions between secondhand smoke and exposure to greenspace and violence.

This study demonstrates the complexity of measuring neighborhood factors and their relationships. Future research in this area should incorporate a larger sample size with greater variability and a longitudinal design.

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Dissertation Organization

This dissertation is organized into five chapters. Chapter 1 includes introductory and background information, study purpose, study aims and hypotheses, and the conceptual framework that provided the foundation for this research. Chapter 2 is presented in three parts. Manuscript 1 (DePriest & Butz, 2017) presents a review of neighborhood factors linked to children's asthma. Manuscript 2 (DePriest, Butz, & Thorpe, 2018) examines the research on neighborhood safety and children's asthma. A third section reviews literature on neighborhood greenspace and children's asthma. Chapter 3 (Manuscript 3; DePriest, Butz, & Gross, 2018) describes the study protocol. Chapter 4 presents the results in two parts. Manuscript 4 presents the findings from testing associations among neighborhood greenspace, violent crime victimization rate, and asthma control (Hypotheses 1, 2A, and 3). The addendum presents findings from testing associations between parent perception of neighborhood safety and asthma control (Hypotheses 2B and 2C). Chapter 5 summarizes the findings, study strengths and limitations, and implications for future research and policy.

CHAPTER 1: INTRODUCTION

Introduction

Currently 6.1 million children in the United States have asthma,[1] costing $81.9 billion annually in healthcare related expenditures and costs related to mortality and absenteeism.[2] Approximately 38% of these children have uncontrolled asthma[3] meaning that they have two or more symptom days per week, at least one symptom night per month, activity limitations, and use rescue medications more than two days per week.[4] Compared to children with controlled asthma, children with uncontrolled asthma have greater impairment, higher use of healthcare resources, and lower quality of life.[5] African American children living in urban poverty are at a disproportionately higher risk for uncontrolled asthma relative to non-Hispanic white children. Racial disparities in asthma outcomes are likely attributable, in part, to differential exposures to neighborhood conditions, since segregation and economic disadvantage influence neighborhood residence. These exposures include unhealthy physical environments (e.g. air pollution,[6-8] poor quality of housing,[9] presence of pests in the home,[10] and exposure to secondhand smoke[11]) and unhealthy social environments (e.g. violence[12,13] and stress[14,15]). For example, children from low-income families are exposed to higher levels of traffic related air pollution; live in lower quality, more crowded, and noisier homes; and are exposed to more neighborhood violence compared to children from more affluent families.[16]

These neighborhood level factors are shaped by political and economic factors and are difficult to change. However, one potentially modifiable factor that may improve asthma control is the availability of greenspace, defined as land with grass, trees, or other vegetation.[17] Prior research indicates that neighborhood greenspace is associated with greater physical activity[18] and social connection[19] and with lower levels of perceived stress,[20,21] environmental heat and air-pollution,[22] variables that are shown to facilitate asthma control in children.[23-26] Indeed, some studies have shown that increases in the normalized difference vegetation index (NDVI), a measure of the greenspace in a given geographical area, is associated with decreased asthma prevalence.[27] However, other studies have shown no effects[28] or negative effects[29,30] of greenspace on asthma prevalence and control. One possible explanation for the mixed results is the failure to account for indicators of neighborhood safety (i.e. violent crime victimization rate, parent perception of neighborhood safety) which would affect parents' willingness to allow their children to use greenspace. Living in an unsafe neighborhood has been associated with greater stress and children spending less time outside[31] resulting in increased exposure to indoor allergens and pollutants, including second hand smoke.[32] Research has demonstrated poor asthma control in areas with high violent crime compared to similar areas with low violent crime.[33]

This study examined the associations among greenspace, neighborhood safety and asthma control in children living in poverty with asthma. Controlling for common asthma triggers in the home, the study examined the relationships among an index of neighborhood greenspace, neighborhood safety (based on violent crime victimization rate and parents' perception of neighborhood safety) and level of asthma control in a sample of 196 low-income, African American children in Baltimore City diagnosed with asthma. The goal of this research was to inform policies and practices for improving health outcomes for children with asthma living in urban poverty by understanding the role greenspace and neighborhood safety might play in asthma control.

Specific Aims

Building on an existing study of children with asthma,[34] this study used multiple measures and informants to capture study variables including geocoding, neighborhood crime statistics, parent reports, and physiologic measures. In a sample of predominantly African American, low-income children living with asthma in Baltimore City the specific aims of this study were:

Aim 1. Examine the association between neighborhood greenspace and level of asthma control. H1: Controlling for allergic sensitization, child asthma medication use, asthma triggers within the home (cockroaches, rats, mice and secondhand smoke), season of enrollment, child demographics and family income, a higher index of neighborhood greenspace (measured as NDVI) will be associated with better asthma control.

Aim 2. Examine the association between neighborhood safety (measured as violent crime victimization rate and parent perception of neighborhood safety) and level of asthma control. Controlling for allergic sensitization, child asthma medication use, asthma triggers within the home (cockroaches, rats, mice and secondhand smoke), season of enrollment, child demographics, family income, and neighborhood social cohesion the hypotheses are as follows: H2A: Higher rates of violent crime victimization will be associated with poor asthma control. H2B: Parent perception of an unsafe neighborhood will be associated with poor asthma control. H2C: Parent perception of neighborhood safety will be more strongly associated with level of asthma control than violent crime victimization rate.

Aim 3. Explore neighborhood safety (violent crime victimization rate and parent perception of neighborhood safety) as a potential moderator in the association between neighborhood greenspace and level of asthma control. H3: Controlling for allergic sensitization, child asthma medication use, asthma triggers within the home (cockroaches, rats, mice and secondhand smoke), season of enrollment, child demographics, family income, and neighborhood social cohesion, neighborhood safety will moderate the relationship between greenspace and level of asthma control such that safer neighborhoods (relative to others in the sample) will strengthen the association between higher index of greenspace and better asthma control.

Background

Low-income, African American children are disproportionately affected by asthma. Asthma is the most common cause of all Pediatric Emergency Department (ED) visits.[35] Repeated ED visits are an index for poorly controlled asthma as children with frequent ED visits are at the greatest risk for life-threatening asthma, decreased quality of life, and increased school absences.[4] Uncontrolled asthma also leads to inflammation and airway remodeling that may contribute to long-term loss of lung function and impairment.[36] According to one study, low-income, African American children have 4.1 times higher ED visits and a death rate 7.6 times higher than rates for non-Hispanic white children.[35] While some researchers are investigating a possible genetic component to these high rates of asthma-related morbidities,[37,38] there is strong evidence that environmental exposures are also important contributors. Environmental factors such as chronic exposures to indoor allergens, secondhand smoke, air pollution, violence, and toxic stress; sedentary lifestyles; and obesity[39] are differentially distributed according to economic disadvantage. Limited access to preventative care in low-income underserved communities also contributes to higher rates of uncontrolled asthma and higher rates of asthma related mortality.[40] The National Asthma Education and Prevention Program Expert Panel Report 3 (NAEPP EPR3), published by the National Heart, Lung, and Blood Institute (NHLBI), identified a history of "low socioeconomic status or inner-city residence" as key risk factors for asthma related mortality.[4] Identifying modifiable factors that can lead to improved asthma control among African American children growing up in poverty has been named a research priority by the Environmental Protection Agency[41] and Healthy People 2020[42] and supports the National Institute of Nursing Research's goal to understand environmental determinants of health in those with chronic disease.[43]

Availability of greenspace may be a protective factor for children with asthma. Greenspace in an urban environment has been shown to decrease environmental heat and air-pollution.[22] Greenspace has also been associated with increased physical activity and social connection and reduced stress and obesity.[44] Given that heat, air pollution, obesity, stress, and sedentary lifestyles are all linked with poorer asthma control some researchers have started to examine whether the availability of greenspace is associated with lower prevalence of asthma and better asthma control. See Figure 1 for the conceptual framework of these relationships.

Several studies have examined the relationship between greenspace and asthma prevalence rates. Although some have found significant relationships suggesting greenspace may have positive effects on asthma rates,[27,45] the few that looked at asthma control did not find significant health effects.[45,46] Although asthma rates are important health indicators, rates of asthma control are stronger indicators of morbidity and mortality risk.[4] This study examined associations between greenspace and indicators of the level of asthma control in a low-income, high risk pediatric population.

It is important to note that not all studies that have examined the relationship between greenspace and asthma prevalence have uncovered significant health effects.[30,47] However, some of these studies were conducted in small cities where asthma rates were low, which may have contributed to floor effects. Some studies were limited by using tree canopy,[48] rather than a stronger measure of greenspace, such as "normalized difference vegetation index" or NDVI. NDVI is a validated, practical measure of greenspace.[49] In all of the studies thus far, none controlled for the effects of neighborhood safety. This study used NDVI to measure neighborhood greenspace in an urban city with higher than average rates of both pediatric asthma and neighborhood violence.

To date, no study has investigated the association between greenspace and pediatric asthma control in low-income, hyper segregated, urban communities. This study addressed the limitations of previous studies by (a) employing a validated method (NDVI) for estimating neighborhood greenspace, (b) focusing on a sample of children at greatest risk for asthma-related morbidity and mortality (i.e., African American children living in urban poverty), and (c) examining the relationship between the availability of neighborhood greenspace and asthma control based on the parent report of symptoms, activity limitations and rescue inhaler use for the child in the preceding weeks.

How does neighborhood safety relate to asthma control? Unsafe neighborhoods are thought to influence asthma control through the stress pathway by inducing an inflammatory response.[50] One study demonstrated that asthmatic children exposed to acute stressors have increased airway inflammation compared to non-asthmatic children; the degree of airway inflammation was found to be greatest among low-income children.[51] This research suggests that chronic stress increases the susceptibility of asthmatic children to acute stressors. Over time, chronic stress exposure can modify the hypothalamic-pituitary-adrenal axis which alters the way individuals physiologically respond to asthma triggers, prompting more frequent exacerbations.[52] An unsafe neighborhood represents one chronic stress exposure that might decrease asthma control for children living in these areas. In two studies utilizing violent crime statistics, areas with higher violent crime rates (in Cincinnati and Chicago) had more asthma ED visits (a proxy for asthma control)[33] and higher asthma prevalence.[53] This body of research, predominantly done in low-income communities, demonstrates a link between safety and asthma control but fails to control for exposure to indoor triggers. This study controlled for indoor triggers and examined two different indicators of neighborhood safety (violent crime victimization rates and parent perception of neighborhood safety) to determine if one measure was a stronger predictor of asthma control.

Which operationalization of neighborhood safety has a stronger association with asthma control? In a recent literature review presenting research on safety and children's asthma[54] there were no studies found that measured neighborhood safety simultaneously as objective and subjective variables. This information would help guide future research into the mechanisms between neighborhood safety and asthma control and support development of interventions to improve asthma control. This study captured neighborhood safety in two ways: neighborhood violent crime victimization statistics and parent perceptions of neighborhood safety. Although it was likely these two estimates of neighborhood safety are related (i.e., parents acquire a perception of neighborhood safety at least in part based on the amount of violent crime occurring in their neighborhood), parent perception of neighborhood safety may be a stronger predictor of child health outcomes than neighborhood crime because perceptions are influenced by several factors including actual crime levels, disadvantage, and individual characteristics.[31] A 2016 study found that when measuring associations between perceived and objective neighborhood violence and adolescent psychological distress, perceived neighborhood violence was associated with psychological distress but there was no relationship between objective neighborhood violence and psychological distress.[55] In this study, neighborhood crime statistics captured averages by census tracts. However, parents may base their assessments of neighborhood safety on a different concept of where their neighborhood falls, a single incident that occurred in an otherwise low-risk neighborhood, or a personal encounter they had, and this may be the reason why they keep their children indoors, none of which may be fully reflected in census tract crime statistics.

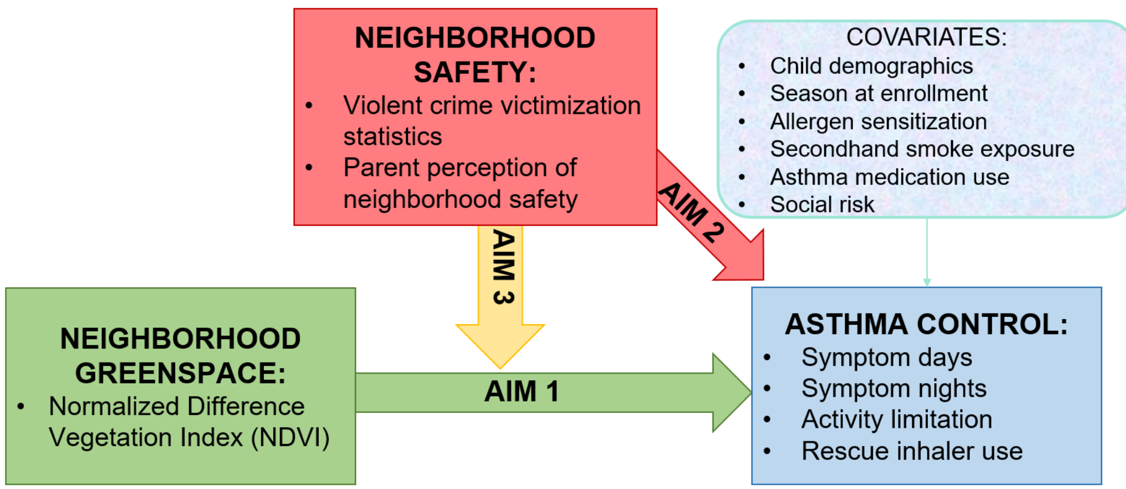
If parent perception of neighborhood safety was a stronger predictor of asthma control than neighborhood crime statistics (Aim 2; H2C), it may suggest that parent stress and perceptions play a more important role in understanding how neighborhood factors affect children's asthma control. Looking at these two indicators of neighborhood safety separately would inform future research into differing mechanisms of the association between neighborhood safety and asthma control.

Neighborhood safety may be a potentially important modifying factor that prevents the use of greenspace. Markers of neighborhood safety such as violent crime, which tend to be higher in low-income neighborhoods,[56] may limit the benefits of greenspace on children's asthma control as parents who perceive their neighborhoods as unsafe are likely to keep their children indoors,[57] which would reduce risk of harm but, also increase their exposure to indoor asthma triggers such as secondhand smoke,[32] and limit their physical activity.[58] Parent perception of neighborhood safety may also affect the parent's level of stress leading to unhealthy coping behaviors such as smoking, which is more common in low-income communities.[58] Secondhand smoke exposure is a known trigger for children with asthma. A recent study examining the associations between family relationships, greenspace, and childhood asthma found statistically significant evidence that in positive psychosocial environments (e.g. positive family relationships) increased amounts of greenspace are associated with better asthma control.[46] This study is one of the first studies to analyze neighborhood safety as a potential modifier in the relationship between greenspace and asthma control in a sample of children at higher risk for asthma related complications.

Conceptual Framework

This study is guided by a conceptual framework (see Figure 1) that was developed through a literature review. While some researchers have presented models incorporating both physical and social factors with asthma control,[58-60] this is the first framework to specifically include greenspace, neighborhood safety, and the interaction between the two variables in their relationship with asthma control. The section of the framework regarding greenspace and asthma control were informed from models by Kuo[61] and Markevych[44] who presented the hypothesized associations between greenspace and health outcomes. The section of the framework regarding safety and asthma control draws heavily on the work of Wright, whose team has several publications on community level contextual factors that influence disease.[62-65] The control variables, which vary for each aim (please see individual hypotheses corresponding to each aim), were chosen by literature review and discussion of known asthma triggers. Overall, this conceptual framework represents the core concepts and relationships that will be included in this study.

Figure 1. Conceptual Framework: Relationships among Neighborhood Greenspace, Neighborhood Safety, and Asthma Control



Significance

Baltimore City leaders have spearheaded several initiatives to increase urban greenspace. One example, the "Green Network Plan" through the Department of Planning and the Office of Sustainability, aims to revitalize communities by interconnecting greenspaces throughout the city.[66] Research accounting for the larger context of neighborhood environment including neighborhood safety will inform more effective implementation of greenspace initiatives in urban areas like Baltimore. This research is also relevant to primary care providers as it supports the growing realization that health goes beyond services provided in clinics and hospitals. This holistic approach recognizes that health, particularly for children with asthma, is influenced by a myriad of factors including both the social and physical environments in which children live.

CHAPTER 2: LITERATURE REVIEW

Introduction

This review of the literature is organized into three sections. The first section is an integrative review analyzing research on the associations of neighborhood-level factors related to children's asthma in urban areas (Manuscript 1; DePriest & Butz, 2017). The second section contains an integrative review analyzing research on the relationship between neighborhood safety and children's asthma (Manuscript 2; DePriest, Butz, & Thorpe, 2018). The third section reviews research on neighborhood greenspace and children's asthma.

MANUSCRIPT ONE: Neighborhood-level factors related to asthma in children living in urban areas: An integrative literature review

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Abstract

Asthma disproportionately affects children who are non-White and of low socioeconomic status. One innovative approach to address these health disparities is to investigate the child's neighborhood environment and factors influencing asthma symptoms. The purpose of this integrative review is to critique research investigating the relationships between neighborhood-level factors and asthma morbidity in urban children. Three literature databases were searched using the terms "asthma," "child," "neighborhood," and "urban." The articles included were organized into six themes within the larger domains of prevalence, physical, and social factors. Literature tables provide in-depth analysis of each article and demonstrate a need for strengthening analysis methods. The current research points to the necessity for a multilevel study to analyze neighborhood-level factors that are associated with increased asthma morbidity in urban children. School nurse clinicians, working within children's neighborhoods, are uniquely positioned to assess modifiable neighborhood-level determinants of health in caring for children with asthma.

Introduction

Asthma disproportionately affects nonwhite children living in poverty. The National Health Interview Survey done by the Center for Disease Control (CDC) in 2014 demonstrated that the lifetime asthma prevalence for “white non-Hispanic” males and females under 18 years old is 14.1% and 10.1%. Compare this data to the percentage for “black non-Hispanic” males and females, (22.7% and 14.8% respectively) and “Puerto Rican” males and females (35.4% and 28.1%)[1] and the differences are quite obvious. This survey also demonstrates a higher asthma prevalence at lower incomes. Despite a long history of research on asthma, the disparities still exist. Original research focused on causes and treatments at the individual level. More recent research has begun to investigate family, neighborhood, and societal factors that may influence childhood asthma. This review analyzes research from the past five years due to the quick pace of developments in the field. Neighborhood level factors are being investigated using sophisticated statistics and accounting for several domains in their modelling.

The neighborhood still remains an important area to investigate because it is linked with severe asthma and greater risk of death. Although there is not one definitive causal factor, it has been proven that residential segregation, both past and present, leads to disparities in socioeconomic status (SES) causing racial health disparities between African Americans and Caucasians.[2] According to a review by Evans, children from low SES families consume more polluted air and water, live in lower quality, crowded, noisier homes, are exposed to more violence, and experience more family instability and chaos compared to their higher SES counterparts.[3] These physical and social affects have negative health consequences for children with asthma. According to the National

Asthma Education and Prevention Program (NAEPP) expert panel report one risk factor for asthma-related death is being of “low socioeconomic status or [an inner-city resident].”[4] Solely by having a lower income or living in an “inner-city” one is at risk for dying from asthma. This statement emphasizes how important it is to investigate the impact of neighborhood level factors on children’s asthma. Analyzing current research in this area will allow scientists to develop interventions to combat asthma at this level. As is mentioned in previous reviews on this topic,[5,6] a multilevel framework would support and encourage multidisciplinary investigation in asthma related research. The purpose of this systematic review is to analyze and critique research from the past five years that investigated the relationships between neighborhood level factors and asthma in children living in urban areas.

Literature Search Methods

A review was performed to understand current research being done to analyze the relationship between neighborhood level factors and asthma in children living in urban areas. A systematic literature search of CINAHL, Pubmed, and PsycINFO databases was conducted with the assistance of a university librarian. Search terms included the Medical Subject Headings (MeSH) terms “asthma” or “status asthmaticus.” For the population the terms “child,” “infant,” “toddler,” “baby,” “teen,” “adolescent,” or “youth” were used. The terms “neighborhood,” “residence,” “community,” or “environment” were used to denote the area. The term “urban” was also used to denote an urban location. The search was performed for the past five years (2010-2015) as research is moving quickly in this area and recent research most appropriately reflects the state of the science. Articles were found from this search as well as a hand search speaking with experts in the field and reviewing reference lists to identify relevant articles. There were no restrictions on primary author discipline, location of the study, or methodological orientations.

The PRISMA flow diagram (Figure 1) illustrates the search process. The inclusion criteria were: full text, published, peer-reviewed, and English language. Studies based on adult asthma, trialing interventions, dissertations, reviews, opinion articles, and articles published prior to 2010 were excluded leaving 26 studies after three additional studies were added from a hand review. The review will be organized conceptually discussing recent research on prevalence as well as physical and social neighborhood level factors that are associated with asthma. The critique follows the results and the article concludes with implications for future research.

Results

Articles were analyzed by type of study, methods, results, asthma measurement, inclusion of sex, race and ethnicity, and SES. During analysis, articles were evaluated critically regarding theoretical and methodological features. After analysis of all articles, six themes emerged organically from the data. The results are presented according to theme below beginning with research of asthma prevalence followed by physical then social neighborhood level factors.

Prevalence

Several recent studies demonstrate that asthma prevalence varies by race as well as socioeconomic status. Two large national studies (n= 1,784; 23,065, respectively) demonstrated that asthma rates are significantly higher for children who are African American[7] or Puerto Rican.[8] These studies also analyzed data by socioeconomic status and one demonstrated that a one unit decrease in the household income to poverty ratio was associated with a 7% increase in the odds of prevalent asthma (95% CI=1.05, 1.10).[7]

A similar study was done with data from the Latin American International Study of Asthma and Allergies in Childhood (ISAAC) to analyze multiple factors relating to asthma prevalence. This study also found that the Gini index, which is a measure of income distribution similar to SES, along with crowding, sanitation, infant mortality rate, and homicide rate, explain 75% of the variance in asthma prevalence in 31 Latin American Urban Centers.[9] This study, along with the two discussed earlier, utilized a cross-sectional design which prevents any causational inferences to be drawn.

Fattore et al measured distal, intermediate, and proximal determinants of wheezing in children.[9] Similarly, Holt et al and Keet et al analyzed data on the sociodemographic, neighborhood, familial, and individual level.[7,8] Holt and colleagues found that the mother's race and ethnicity, child's insurance coverage, child's sex, allergies, the physical condition of the exterior of the home, and the percent of the population with a bachelor's degree were significantly associated with an asthma diagnosis by age 5 when adjusting for several confounding variables.[8] Keet and colleagues found that race and ethnicity were strongly associated with asthma prevalence but in a multivariable analysis they found that neighborhood poverty and urban/rural status were not risk factors.[7] It should be noted that Keet et al did not sufficiently power their analysis to measure asthma morbidity as an outcome and therefore cannot state that neighborhood or urban/rural status does not play a role in asthma morbidity. In a similar study, Ownby and colleagues demonstrated that asthma prevalence, when controlling for socioeconomic status, is similar among rural and urban African American teens.[10] The data also included morbidity and demonstrated that the teens living in urban Detroit reported more symptoms and hospitalizations in the past 30 days. The cross-sectional data was from self-report questionnaires that were sent out to students through public schools in the area which do not take into account possible absenteeism due to asthma or the number of children in the area who attend private schools. The populations were also sampled three years apart and environmental characteristics were not taken into account in the analyses. Although there have been unique findings, as demonstrated by Ownby et al,[10] there should be methodologically stronger research done to support this evidence that urban versus rural location does not correlate with asthma. Taken together, this body of research demonstrates that asthma disproportionally affects African American and Puerto Rican children in the United States and it seems to correlate with socioeconomic status nationally and internationally. There is a discrepancy as to whether or not urban versus rural status is associated with increased asthma prevalence, however being an "inner-city resident" is cited as a risk factor for asthma mortality and it is important to continue to investigate what elements of this environment are related to asthma prevalence and morbidity.

Physical- Outdoor Air

Research of outdoor air quality ranges from analyzing pollen related to asthma emergency department (ED) visits[11] to the impact of weather[12]and particular air pollutants[13-17] on asthma and respiratory health. Some of the research has mixed results. Jariwala et al was the only study that found a correlation between pollen and asthma emergency department visits ($r=0.9$, $p=0.0374$) but could not demonstrate a relationship between nitrogen oxides (NOx) or ozone (O3) peaks and peak visits for asthma to the emergency department.[11] One possible reason is that the environmental data was recorded for large areas and not linked more specifically with individual homes.

Glad et al utilized a case-crossover design to demonstrate a 2.5% increase in asthma ED visits for every 10 parts per billion (ppb) increase in ozone level (OR=1.025, $p<0.05$).[13] The case-crossover design may have strengthened the method, but the pollution data was obtained from a limited number of monitors and therefore did not capture variability across regions. Through a retrospective case-control study Nishimura et al demonstrated a 5ppb increase in average nitrogen dioxide (NO_2) during the first year of life was associated with an odds ratio of 1.17 for asthma (95% CI 1.04-1.31).[14] This study also demonstrated significant relationships between specific pollutants and asthma for differing cities in the United States. The study design addressed temporality of air pollution and allows for causal inferences, but the data was analyzed as large areas rather than particular homes of the study participants. Svendsen et al demonstrated in Texas that a 10ppb increment increase in NO_2 levels was associated with current asthma (OR=1.65, 95% CI 1.08-1.65) for children in public schools at elevations above 1,170 meters.[15] In valley schools the relationship was not significant. This analysis controlled for indoor sources of exposure including gas stoves and secondhand smoke.

Buonanno et al and Vieira et al were able to measure individual pollutant exposure, thereby strengthening their inferences. In Italy, Buonanno et al demonstrated that children in urban areas are exposed to particle concentrations 25% higher than the overall mean exposure ($p<0.01$).[16] He also demonstrated that home was a major contributor (57%) to daily dose of airborne particles and that there is an association between personal dose and respiratory health effects. Vieira et al demonstrated a low cost method to measure NO_2 and O_3 exposure for children by using small air filters in their homes, balconies, and hooked onto their backpacks.[17] Although the sample size was small (n=64), the study found that the NO2 in indoor air and personal exposure to O3 were independently associated with asthma ($p=0.02$ for both) and wheezing at any time ($p<0.01$). This data supports research that air pollution in the form of nitrogen dioxide and ozone do relate to asthma and their exposure early in life may increase odds of an asthma diagnosis. Overall there appears to be strong evidence supporting an association with NO and asthma and not as much information on O3 with limited research on pollen. More research should be done on individual level exposures possibly by the methods used by Vieira and colleagues[17] to measure outdoor, indoor, and personal exposure.

Physical- Outdoor Air- Traffic

In looking more specifically at traffic related pollution, Cook, deVos, Pereira, Jardin, & Weinstein[18] and Li, Batterman, Wasilevich, Elasaad, Walg, & Mukherjee[19] used proximity of houses to major roads and estimated traffic counts to analyze asthma. They both used case-control studies to demonstrate increased risk of asthma related events such as emergency department visits. Cook et al demonstrated that in Perth, Australia there is a 24% increase in the risk of experiencing multiple emergency contacts for asthma for every log-unit of traffic exposure (95% CI 1.00-1.52).[18] Li et al demonstrated that in Detroit, Michigan for every 1 km increase in distance away from a primary road the odds ratio of an asthma event is 0.97 (95% CI 0.94-0.99).[19] Although they used large sample sizes (n=434[18] and n=14,646[19]), neither study took into account SES, sex, or ethnicity, which might explain some of the variation in asthma events. The data did not account for other exposures such as secondhand smoke, family history, or indoor air pollutants and allergens because it was de-identified from hospital records in Australia and Medicaid data in Detroit. Although this information does not demonstrate causation, taken with the data about specific pollutants there appears to be an association between outdoor air quality and asthma.

Physical- Indoor Air- Triggers and Housing

Recent research on triggers and housing analyzes types of housing,[20] specific triggers,[21,22] and behaviors aimed at decreasing triggers. [23,24] Northridge et al determined that there is a high prevalence of asthma in public housing (21.8% 95% CI 17.3-26.3) in New York City after adjusting for other factors and those in public housing were more likely to report the presence of cockroaches (68.7% versus 21%) compared to other types of housing.[20] Those living in public housing are also less likely to use an air conditioner (50.6% versus 75.1%). This data did not measure psychosocial stressors. Those who did not provide an address, possibly due to unstable residence and higher asthma prevalence, were excluded from the study possibly biasing results toward the null.

Olmedo et al used a case-control design to analyze high asthma prevalence neighborhoods (HAPNs) compared to low asthma prevalence neighborhoods (LAPNs). Bed dust was tested for allergen and in HAPNs there was more cockroach (22 ng/g versus 37ng/g), mouse (41 ng/g versus 93ng/g), and cat allergen (30ng/g versus 56 ng/g) and lower dust mite (10ng/g versus 5.3ng/g).[22] The author theorized that air conditioning was less common in HAPNs and therefore the dry air was less conducive to dust mites. Of note, cases were more likely to be African American or Hispanic and had a lower income compared to controls so there may be confounding that was not accounted for during analysis.

Another type of asthma trigger, analyzed by Butz et al,[21] is exposure to secondhand smoke measured through urine cotinine levels. Although it was not significant, children with a greater number of symptom days had the highest cotinine concentrations. Data also indicated a two-fold increase in urine cotinine concentrations when the caregiver of the household smoked. The sample consisted of children with uncontrolled asthma, so the lack of variability may have led to the lack of statistical significance. The study also demonstrated that urine cotinine, as opposed to passive nicotine sampling badges in the environment, should be considered the gold standard for measuring secondhand smoke exposure in children. Martin and colleagues also utilized cotinine data in saliva to analyze asthma triggers for Puerto Ricans in Chicago.[23] Caregivers of children with asthma were asked to answer 12 items to determine their trigger behavior summary score. More than half of the sample (n=101) families, had recent construction in or near their home and more than half owned at least one pet. Greater than half had treated their home for cockroaches either personally or professionally and one-third had treated for rats/mice either personally or professionally. Forty-three percent of caregivers reported once a month or more of tobacco exposure for their child, but salivary cotinine data showed less smoke exposure. The salivary cotinine data only accounts for the exposure in the past 24 hours so it could be that there was decreased exposure in anticipation of the interviewer visiting.

Yinusa-Nyahkoon et al analyzed qualitative data to address family routines and asthma management in African American families (n=19) in Boston, Massachusetts.[24] Two of the four main themes were that caregivers worked to manage the air quality in their home and frequently cleaned the home to remove triggers. Over half of the study sample lived above the poverty line, almost half lived in two-parent houses, and all had health insurance and a regular source of ambulatory care. Although this study may not be transferable to “inner city” populations, as the title claims, it is still useful information on how female, African American caregivers have developed routines to care for their young children with persistent asthma.

Social- Outdoor- Safety

Measuring safety was done both directly by looking at crime data[25] and indirectly by measuring perception of safety.[26,27] Gupta et al utilized surveys of children in kindergarten through eighth grade (n=45,371) by geocoding 247 Chicago neighborhoods and dividing them into quartiles based on asthma prevalence.[25] This data was analyzed with crime data from the Chicago Police Department. Criminal activity was significantly ($p<0.001$) higher in neighborhoods with high asthma prevalence. After adjusting for community race and ethnicity, violent crime continued to contribute to explain 15% of the variation in childhood asthma ($p<0.05$). This data did not account for unreported criminal acts but that would mean that incidence was underestimated. This study demonstrated the utility of directly measuring crime while Coutinho et al[26] and Vangeepuram et al[27] measured perceived safety.

Coutinho et al utilized mixed methods to analyze caregiver/child dyads (n=147) and their perception of safety related to family asthma management.[26] There were significant ethnic group differences by poverty status [$F_{(2,120)} = 6.49$ $p<0.01$]. There were also differences in perceived safety by ethnicity [$F_{(2, 124)} =6.29$ $p<0.01$]. Ratings of effective family management positively correlated with home and neighborhood safety ($r=0.36$ $p<0.01$) and negatively correlated with perceived discrimination ($r=-0.19$ $p<0.05$), and acculturative stress ($r=-0.21$ ($p<0.05$). Vangeepuram et al used cross-sectional data of parents (n=504) of 6-8 year old children with asthma in New York

City.[27] They found that parents who reported feeling unsafe walking in the neighborhood were more likely to have a child diagnosed with asthma (OR=1.89 95% CI=1.13-1.34). An interesting finding in this data is that the neighborhoods sampled were relatively similar, but it was the variation in parent perception of safety that related to asthma prevalence. All three of these studies demonstrate that direct and indirect measures of safety may be correlated with asthma.

Social- Indoor- Family Stress

Family stress is analyzed in several different ways taking into account the family,[28,29] the parent,[30-32] or the child.[33] Family level data was obtained by Koinis-Mitchell et al[28] and Sampson et al[29] using mixed methods. The data Sampson et al presented demonstrated that caregivers (n=40) of children with asthma from low income families in Detroit, Michigan do not see caring for an asthmatic child as a source of stress.[29] They report high stress related to asthma related change, uncertainty, control, and anxiety but did not associate that stress with their child. This information supports the notion that stress-related scales need to continue to be validated on various populations. Analysis of single parents from their sample reported slightly lower quality of life, higher depression, lower income, and more chronic illness, although the data was not statistically significant due to the small sample size. Several stress scales are validated on parents in two-parent homes and therefore the scales may not be valid for a population of single parents.

Koinis-Mitchell and colleagues calculated a Cumulative Risk Index (CRI) to quantify risk factors for asthma.[28] The study showed that cumulative risks were associated with increased functional limitation ($r=0.25$ $p<0.01$) and risk for an ED visit in the past 12 months ($r=0.15$ $p<0.05$). Quinn et al analyzed both parent perceptions of collective efficacy and neighborhood order for a sample of low-income Chicago families with a child who has asthma.[32] Parent health was associated with collective efficacy (Risk Difference $_{\text{low versus high}}$ = 20.9 95% CI 7.8-33.9). General health outcomes of the family, including parents, were associated with collective efficacy but child respiratory health outcomes were associated with neighborhood order. There were no biological or behavioral risk factors accounted for in the statistical analysis and the authors note that reverse causality may be a limitation since asthma may cause stress. Due to the cross-sectional design of this study causality cannot be demonstrated.

Mathilda-Chiu et al[30] and Otsuki et al[31] both utilized prospective designs to demonstrate temporality between maternal stress and depressive symptoms and wheeze and asthma morbidity (respectively). Mathilda-Chiu et al analyzed maternal stress during the prenatal and postnatal period and then subsequent wheeze as reported by predominantly Latina (55%) and African American (29%) mothers in Boston, Massachusetts.[30] Her large sample (n=989) demonstrated that children born to mothers with high stress in both pregnancy and the postpartum period were significantly more likely to have repeated wheeze (adjusted OR 3.04 95% CI 1.67-5.53) compared with children of mothers reporting low stress in both periods. The study assumed that wheeze was a proxy for those that may be more likely to develop asthma or have compromised lung function. Otsuki et al analyzed data from baseline and six months into an intervention on maternal depressive symptoms and child asthma morbidity.[31] This large sample (n=262) of African American mothers of children with asthma demonstrated that maternal depressive symptoms at baseline predicted children’s asthma symptoms six months later (B=0.15, p<0.01). It was shown that maternal depressive symptoms at baseline did not predict asthma ED visits at six months, but the sample was recruited from the ED during high morbidity so that data may not be the best outcome measure.

Koinis-Mitchell et al used cross-sectional data from two separate studies (n=208 total) to analyze children's stress perception related to their asthma.[33] Children with poorly controlled asthma reported a higher rate of neighborhood stress compared to children with well-controlled asthma [$F_{(1, 145)} = 4.5$ (p=0.04)]. This mixed methods exploratory study also allowed the researcher to investigate child perceptions of stressors. The family moving was most frequently endorsed (43%) as a stressor for respondents. Children with poorly controlled asthma reported higher levels of stress related to being afraid to go outside compared to children with well controlled asthma [$F_{(1, 145)} = 6.1$ (p=0.02)]. The study authors reported that a limitation was that there was not a parent instrument to corroborate children's perceptions of concepts, but the mixed methods nature of the study allowed the children to explain their answers.

Discussion

SES, Race and Ethnicity, Sex

Please refer to tables 1-6 for detailed analysis of each individual article. In general, the international articles did not identify race and ethnicity of their samples. Two of the four international articles did mention the socioeconomic status (SES) of their sample because they were looking at social inequity as the main variable related to asthma.[9,17] The data from the United States also frequently accounted for SES. It was operationalized different ways; Northridge et al,[20] Holt et al,[8] and Keet et al[7] used census data as a proxy for neighborhood SES, some discussed where sample participants lived relative to the poverty line,[24,29] one was not able to get SES information due to the type of data they were using,[19] and several mentioned "controlling for SES" in analysis.[10,25-27,30] By controlling for SES there is no way to determine how much influence it may have on the outcome variable. Race and ethnicity were discussed in most of the research from the United States because of the racial disparity associated with asthma. More than half of the studies from the United States sampled specifically African American and/or Puerto Rican children due to the high prevalence of disease amongst this race and ethnicity. Several of the studies analyzed sex as it related to the outcome variable. A few of them had small sample sizes so this stratification was not possible. Several of the stress studies sampling caregivers ended up with predominantly female caregivers as their sample. Because there was always a high percentage of caregivers who were female it was noted but data was never analyzed separately depending on the sex of the caregiver.

Methods

As mentioned in the results section, a common method for these studies is cross-sectional. See tables 1-6 for analysis of specific methods for each article. Data was frequently from baseline questionnaires of intervention studies or other types of secondary data. This data can be useful, but it prevents an inference of causation between variables. It was also frequently gathered retrospectively and missing measurement of important variables. The few prospective studies were helpful to infer causation related to maternal mental health and wheezing[30] and asthma morbidity.[31] Prospective data add temporality to relationships which is one of the criteria for demonstrating causality.

The article by Otsuki et al was also the only article to use Path analysis to model complex relationships between several variables over time.[31] Another frequent analytic technique was logarithmic regression, which is appropriate given binary outcome data. While logarithmic regression can test for confounding or effect modification, it does not allow for modeling complex relationships like Path analysis or mixed effects modelling. Another statistical trend was to dichotomize, or group data originally gathered continuously. This change in the level of statistical analysis from parametric to non-parametric weakens the strength of the evidence. Some authors noted this as a limitation, but others accepted it as a requirement of their study due to non-normal distributions of results.

Sample selection also varied across studies as shown in the studies that sampled from medical records such as: ED data, primary care clinics, Medicaid data, and urgent care call centers. Each type of medical data lends itself to a different sample and therefore results should be interpreted within that sample and are not generalized any further. Several studies also sampled from schools which have implications depending on whether they are public versus private, and the specific demographics of their students. A few of the studies were explicit in their reasoning for sampling at a specific school but others neglected to present this information in their article. The sampling method is different depending on the purpose and pragmatic challenges of the study, but authors must be sure to include their rationale and in the limitations sections their understanding of bias introduced for their chosen method.

A critique of the methods for most of the outdoor air pollution studies, aside from the study by Vieira et al., was the lack of individualized data for each study participant. Using generalized air pollution data does not appropriately estimate the amount of exposure to air pollution that a particular child may experience. Vieira et al used a unique and inexpensive method for attaching air filters to children's backpacks and placing them around their homes for a more precise estimate of exposure.[17] This study demonstrated a cutting-edge method, while some of the others presented limitations.[20,23]

Asthma Operationalization

Tables 1-6 also mention how asthma is operationalized in each study. Some studies utilized health care data and ICD-9 or ICD-10 diagnosis of asthma or "status asthmaticus." One issue that could occur with this data is that if a patient is visiting their primary care practitioner for a non-respiratory matter, this appointment may flag as an asthma related appointment and therefore bias the results. With a previous diagnosis of asthma, there was no way to determine if the individual visit was asthma related or due to another health issue. Several studies asked for parents to report whether or not their child had physician diagnosed asthma and symptom frequency. Self-report can be limiting if the caregiver cannot recall this diagnosis or frequency of symptoms. This might happen if the child is in daycare, if the parent works long hours, or if more than one child has asthma. In order to strengthen this operationalization, some studies would require report of physician diagnosed asthma as well as pulmonary function tests. Of note, other healthcare providers, Nurse Practitioners for example, also frequently diagnose asthma. The term "physician diagnosed" asthma is frequently used but does not account for these health care providers. Some further stratified type of asthma by analyzing parent report of control, severity, and functional limitation. Another common theme was to look at ED visits for exacerbation. There are several different ways to study asthma as long as the operationalization matches the study purpose and does not draw erroneous conclusions. Several studies cited the NAEPP expert panel guidelines for how they measured asthma.[4]

This resource, from the National Heart Lung and Blood Institute of NIH provides details on how to diagnose asthma severity and assess persistence and control and provides a good universal method to operationalize this concept.

Limitations

This review has some limiting factors. One possible limitation of this review is the inclusion criteria that articles were from the last five years. Although this time frame was justified considering constant advances in the field, some important articles might have been excluded. Research over the past five years appeared to build on previous research so expanding the search timeframe might not have added any significant articles. There is also a chance that search terms related to neighborhood level factors were not included in the search. For this reason, a university librarian was consulted to help design the search. MeSH terms as well as search terms were used to attempt to capture all of the required terms without being too specific but there is a chance that an important term was excluded. Another possible limitation was the use of the term "urban" in the inclusion criteria. Some of the articles in the review demonstrated that urban vs. rural status may not be an important factor in asthma prevalence. Although this may be true, the focus on this review was urban children and therefore it was a critical search term to be included.

Implications for Future Research

There are specific as well as general suggestions for future research in the above areas. Research into prevalence should be clear about what is being measured. There was moderately strong evidence presented that argued that socioeconomic status, and not place, is what drives asthma disparities. Prevalence research should attempt to replicate the work of Ownby et al[10] using stronger sampling techniques to be sure all students in an area are included and physiologic testing in addition to asthma self-report to strengthen the validity of the outcome variable. Fattore et al recommended continuing prevalence studies discriminating between phenotypes of asthma, addressing the geographic and individual level, and incorporating variables related to socioeconomics and urbanization.[9,26] On that note, as it was suggested several times, outdoor air pollution data needs to use more individualized methods.[16,17] If these small-scale studies are done frequently in differing populations, climates, and geographic areas then a meta-analysis would help to draw conclusions about overall risk for humans.[13]

Nishimura et al also reported that increased exposure to nitrogen dioxide in the first year of life statistically significantly increased the odds of being diagnosed with asthma but the regions where study participants lived had NO2 levels lower than the EPA air quality standard.[14] This suggests the need for further research to specifically test NO2 levels. Current EPA requirements may not be sufficient to protect the health of children and the EPA standards might need to be increased. The studies relating proximity to traffic and asthma also represent areas where public health indicated changes in policy are needed. This environmental health issue should be investigated further particularly in the school environment where school buses park emitting exhaust while waiting to load children.

Several of the studies[20,23,24] discussing indoor air suggest a multipronged approach to reducing home triggers. There should be more research and interventions targeting the individual level whether that is smoking cessation[21] or discussion of how to eliminate other triggers such as; cockroaches, mold, etc., as well as policy changes around housing, pollution control, and tobacco legislation. Northridge et al[20] noted that because many of the houses are multi-unit dwellings the families living inside them have limited control over the maintenance of the spaces and therefore limited ability to control triggers that affect their children. Therefore, policy changes around housing for those on government assistance should take into account the health of children in determining what type of building meets their requirements.

The safety research demonstrated correlations between actual crime in neighborhoods,[25] perceived safety,[26,27] and asthma. All three studies recommend additional research in this area to investigate the mechanisms behind the associations,[26] specific psychological measures related to violence exposure,[27] and control for potential confounders in the built environment.[25] More data is needed in this area to develop interventions to treat this problem. Regarding other sources of stress, future research should continue to investigate the mechanisms of how chronic stress effects children over time. The range of studies recommended looking at maternal depression starting in pregnancy, evaluating interventions to treat the depression, and further investigating the relationship between prenatal depression and future wheeze. Stress studies need to analyze psychological and physiological effects of stress while taking into account the other variables noted to affect asthma including the physical environment.

Analyzing the current research in neighborhood level factors affecting asthma clearly shows that the next step is multi-level research into factors associated with asthma. As mentioned earlier, mixed effects modelling would be the optimal statistical analysis due to complex relationships between many differing levels of variables. Socioeconomic status, for example, is related to asthma and demonstrated by research in this review and previous research, but it acts through different mediators such as housing.

To appropriately measure the relationship between SES and asthma several pathways need to be included in the model to examine multiple associations between these variables and therefore mixed effects modelling is the best statistical analysis to use with this type of data. This review has analyzed the latest research on neighborhood level factors that affect asthma in children living in urban environments. The current research has demonstrated a gap in studies analyzing multiple levels of influence through advanced statistical methods. This data can be used to better understand relationships of multiple factors as well as to influence health policy to improve the neighborhood environment for those children most affected by asthma.

Implications for School Nurse Clinicians

This review directly applies to school nurse clinicians who frequently monitor and care for children with asthma. As healthcare providers, working in the community where high-risk children reside, they should be informed of the physical and social neighborhood level factors that contribute to childhood asthma. They have a unique opportunity to target educational and behavioral interventions towards these determinants of health. This review also serves as a reminder to assess children with asthma holistically, within the context of their physical and social neighborhood environment.

References

1. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. National Center for Health Statistics (2014). 2014.
2. Williams D, Collins C. Racial residential segregation: A fundamental cause of racial disparities in health. *Public Health Reports (1974-)*. 2001;116(5):404-416. https://www.jstor.org/stable/4598675. doi: 10.1016/S0033-3549(04)50068-7.
3. Evans GW. The environment of childhood poverty. *American Psychologist*. 2004;59(2):77-92. http://www.ncbi.nlm.nih.gov/pubmed/14992634. doi: 10.1037/0003-066X.59.2.77.
4. U.S. Department of Health and Human Services, National Heart, Lung, and Blood Institute. The national asthma education and prevention program. expert panel report 3 (EPR3): Guidelines for the diagnosis and management of asthma. 2007.
5. Wright RJ, Subramanian SV. Advancing a multilevel framework for epidemiologic research on asthma disparities. *CHEST Journal*. 2007;132(5 Suppl):769S. http://journal.publications.chestnet.org/content/132/5_suppl/757S.abstract. doi: 10.1378/chest.07-1904.
6. Schreier HMC, Chen E. Socioeconomic status and the health of youth: A multilevel, multidomain approach to conceptualizing pathways. *Psychological bulletin*. 2013;139(3):606-654. http://www.ncbi.nlm.nih.gov/pubmed/22845752. doi: 10.1037/a0029416.
7. Keet CA, McCormack MC, Pollack CE, Peng RD, McGowan E, Matsui EC. Neighborhood poverty, urban residence, race/ethnicity, and asthma: Rethinking the inner-city asthma epidemic. *J Allergy Clin Immunol*. 2015;135(3):655-662.
8. Holt EW, Theall KP, Rabito FA. Individual, housing, and neighborhood correlates of asthma among young urban children. *J Urban Health*. 2013;90(1):116-129.
9. Fattore GL, Santos CAT, Barreto ML. Social determinants of childhood asthma symptoms: An ecological study in urban Latin America. *Journal of Community Health: The Publication for Health Promotion and Disease Prevention*. 2014;39(2):355-362.
10. Ownby DR, Tingen MS, Havstad S, Waller JL, Johnson CC, Joseph CL. Comparison of asthma prevalence among African American teenage youth attending public high schools in rural Georgia and urban Detroit. *J Allergy Clin Immunol*. 2015;136(3):600.e3.
11. Jariwala SP, Kurada S, Moday H, et al. Association between tree pollen counts and asthma ED visits in a high-density urban center. *J Asthma*. 2011;48(5):442-448.
12. Wanka ER, Bayerstadler A, Heumann C, Nowak D, Jorres RA, Fischer R. Weather and air pollutants have an impact on patients with respiratory diseases and breathing difficulties in Munich, Germany. *Int J Biometeorol*. 2014;58(2):249-262.
13. Glad JA, Brink LL, Talbott EO, et al. The relationship of ambient ozone and PM(2.5) levels and asthma emergency department visits: Possible influence of gender and ethnicity. *Arch Environ Occup Health*. 2012;67(2):103-108.
14. Nishimura KK, Galanter JM, Roth LA, et al. Early-life air pollution and asthma risk in minority children. the GALA II and SAGE II studies. *Am J Respir Crit Care Med*. 2013;188(3):309-318.

15. Svendsen ER, Gonzales M, Mukerjee S, et al. GIS-modeled indicators of traffic-related air pollutants and adverse pulmonary health among children in el Paso, Texas. *Am J Epidemiol*. 2012;176 Suppl 7:131.
16. Buonanno G, Marks GB, Morawska L. Health effects of daily airborne particle dose in children: Direct association between personal dose and respiratory health effects. *Environmental Pollution*. 2013;180:246-250. http://www.ncbi.nlm.nih.gov/pubmed/23792384. doi: 10.1016/j.envpol.2013.05.039.
17. Vieira SE, Stein RT, Ferraro AA, et al. Urban air pollutants are significant risk factors for asthma and pneumonia in children: The influence of location on the measurement of pollutants. *Arch Bronconeumol*. 2012;48(11):389-395.
18. Cook AG, deVos, Annemarie J B M, Pereira G, Jardine A, Weinstein P. Use of a total traffic count metric to investigate the impact of roadways on asthma severity: A case-control study. *Environmental health : a global access science source*. 2011;10(1):52. http://www.ncbi.nlm.nih.gov/pubmed/21631953. doi: 10.1186/1476-069X-10-52.
19. Li S, Batterman S, Wasilevich E, Elasaad H, Wahl R, Mukherjee B. Asthma exacerbation and proximity of residence to major roads: A population-based matched case-control study among the pediatric Medicaid population in Detroit, Michigan. *Environ Health*. 2011;10:34.
20. Northridge J, Ramirez OF, Stingone JA, Claudio L. The role of housing type and housing quality in urban children with asthma. *J Urban Health*. 2010;87(2):211-224.
21. Butz AM, Breysse P, Rand C, et al. Household smoking behavior: Effects on indoor air quality and health of urban children with asthma. *Matern Child Health J*. 2011;15(4):460-468.
22. Olmedo O, Goldstein IF, Acosta L, et al. Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in new york city. *J Allergy Clin Immunol*. 2011;128(2):292.e7.
23. Martin MA, Thomas AM, Mosnaim G, Greve M, Swider SM, Rothschild SK. Home asthma triggers: Barriers to asthma control in Chicago Puerto Rican children. *J Health Care Poor Underserved*. 2013;24(2):813-827.
24. Yinusa-Nyahkoon L, Cohn ES, Cortes DE, Bokhour BG. Ecological barriers and social forces in childhood asthma management: Examining routines of African American families living in the inner city. *J Asthma*. 2010;47(7):701-710.
25. Gupta RS, Zhang X, Springston EE, et al. The association between community crime and childhood asthma prevalence in Chicago. *Ann Allergy Asthma Immunol*. 2010;104(4):306 8p.
26. Coutinho MT, McQuaid EL, Koinis-Mitchell D. Contextual and cultural risks and their association with family asthma management in urban children. *J Child Health Care*. 2013;17(2):138-152.
27. Vangeepuram N, Galvez MP, Teitelbaum SL, Brenner B, Wolff MS. The association between parental perception of neighborhood safety and asthma diagnosis in ethnic minority urban children. *J Urban Health*. 2012;89(5):758-768.
28. Koinis-Mitchell D, McQuaid EL, Jandasek B, et al. Identifying individual, cultural and asthma-related risk and protective factors associated with resilient asthma outcomes in urban children and families. *J Pediatr Psychol*. 2012;37(4):425-437.

29. Sampson NR, Parker EA, Cheezum RR, et al. 'I wouldn't look at it as stress': Conceptualizations of caregiver stress among low-income families of children with asthma. *J Health Care Poor Underserved*. 2013;24(1):275-288.
30. Mathilda Chiu YH, Coull BA, Cohen S, Wooley A, Wright RJ. Prenatal and postnatal maternal stress and wheeze in urban children: Effect of maternal sensitization. *Am J Respir Crit Care Med*. 2012;186(2):154 8p.
31. Otsuki M, Eakin MN, Arceneaux LL, Rand CS, Butz AM, Riekert KA. Prospective relationship between maternal depressive symptoms and asthma morbidity among inner-city African American children. *J Pediatr Psychol*. 2010;35(7):758-767.
32. Quinn K, Kaufman JS, Siddiqi A, Yeatts KB. Stress and the city: Housing stressors are associated with respiratory health among low socioeconomic status chicago children. *J Urban Health*. 2010;87(4):688-702.
33. Koinis-Mitchell D, Kopel SJ, Salcedo L, McCue C, McQuaid EL. Asthma indicators and neighborhood and family stressors related to urban living in children. *Am J Health Behav*. 2014;38(1):22-30.

Figure 1. Prisma Flow Diagram

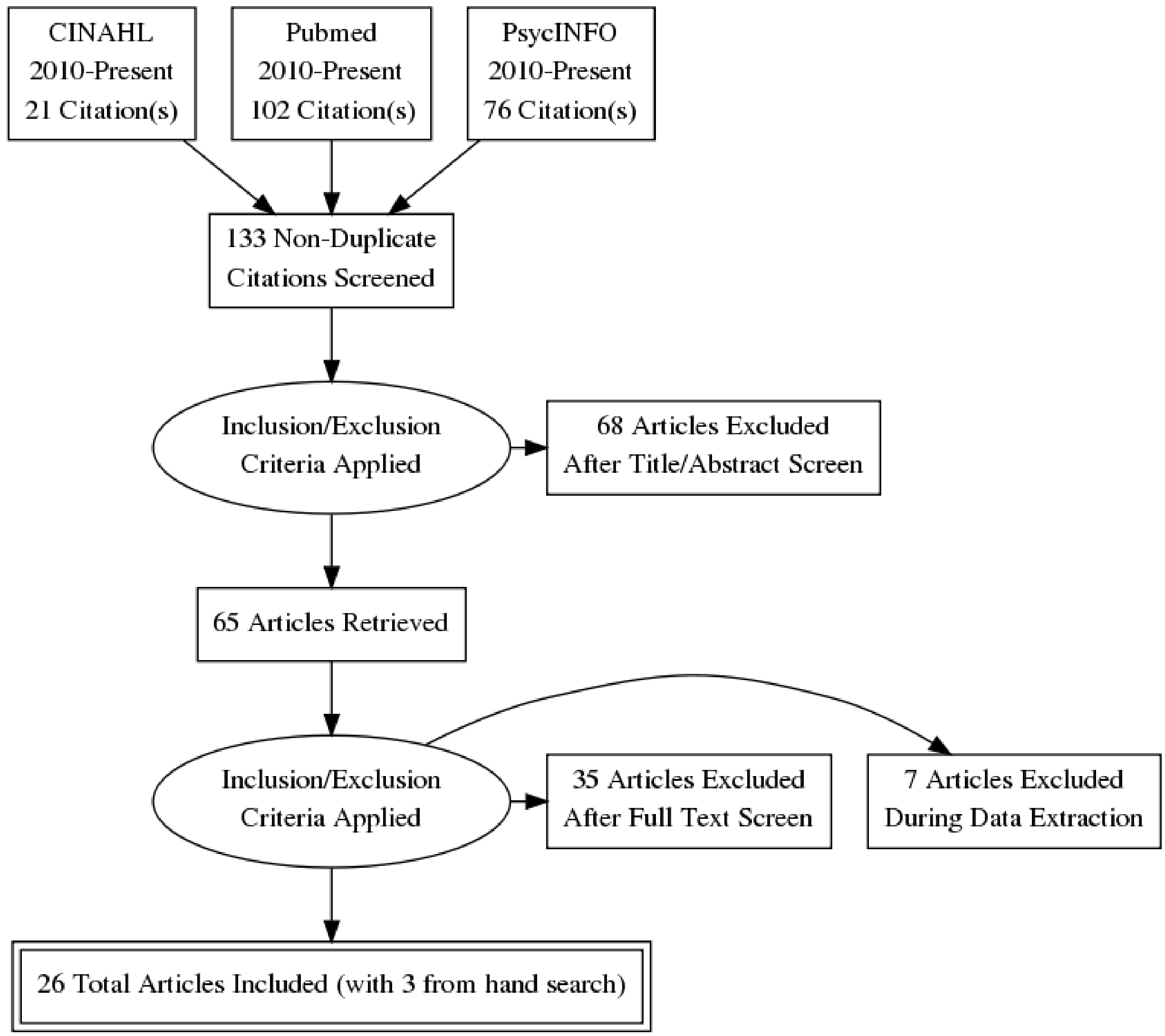

Table 1. Prevalence

Author	Study	Methods	Results	Critique	Asthma	Sex, Race + Ethnicity, SES
Fattore (2014)[9] QUANTITATIVE Latin America	Social determinants of childhood asthma symptoms	Cross-sectional= ecological analysis from n= 31 Latin American Urban Centers. Children aged 6-7. Data from International Study of Asthma and Allergies in Childhood (ISAAC).	Correlation b/t current wheezing and Gini index (SES measure) r=0.42 p=0.01, HDI (human development index) r=-0.47, p=0.008, crowding r=-.048, p=0.005, water supply r=0.35 p=0.07 and homicide mortality rate r=0.32 p=0.07. 3-level model demonstrates that Gini index, crowding, sanitation, IMR and homicide rate explain 75% of variance in asthma prevalence in urban centers.	Cross-sectional= no causal inference. Did not distinguish levels of variables. Secondary data w/ variability in quality. No sample size given. Unsure of diagnosis versus wheeze in past 12 months. Large sample of large area. No analysis between urban centers.	Number of children with wheeze in past 12 months.	Social inequities as main variable- Gini Index- Measure of income distribution. No discussion of sex. All in the sample Latin American.
Holt (2013)[8] QUANTITATIVE USA	Individual, housing + neighborhood correlates of asthma	Cross-sectional= n=1,784 mothers of children in 20 cities. Secondary data	Mother's race and ethnicity, child's insurance coverage, child's sex, allergies, the physical condition of exterior home, and the percent of the population with a bachelor's degree remained significantly associated with asthma diagnosis by age of 5.	Self-report data. Residual confounding may have existed due to a priori categorization of variables such as education or income. Assumption that neighborhood condition was continuous over time. Unmarried mothers were oversampled = generalizable. Large sample size. Focused on black and Puerto Ricans.	Parent report- health professional diagnosis of asthma by age 5. Also asked about symptoms in the past 12 months.	SES by census tract. Data analyzed by gender, SES, and race and ethnicity
Keet (2015)[7] QUANTITATIVE USA	Prevalence of asthma in children living in inner-city= examine residence, poverty, + race and ethnicity r/t disparities	Cross-sectional= n=23,065 Children aged 6-17 in 5,853 census tracts. Data from National Health Interview Survey (NHIS) Inner-city defined as ≥20% of households at or below the poverty line.	Black race + Puerto Rican ethnicity= strong, independent predictors of asthma.10 % inc. in # of households below poverty line assoc. w/ 10% increase in the odds of prevalent asthma (OR 1.10 95% CI 1.05-1.14) Not significant in adj. analysis. 1-unit decrease in household income to poverty ratio assoc. w/ 7% inc. in the odds of prevalent asthma (95% CI 1.05-1.10 p<0.001). Neighborhood poverty urban/rural status were not risk factors in adj. analyses	No multilevel modelling due to sample. Residential confounding as an explanation for the association between race/ethnicity and asthma. Self-report data. Bias r/t who is diagnosed. Survey was done in 2009-2010 but census data was from 2000. Did not sufficiently measure asthma morbidity therefore cannot exclude the possibility that residence in an urban area and poverty may have a stronger role in asthma morbidity than prevalent asthma.	Parent report= healthcare professional diagnosed + symptoms over past 12 months.	Black, Asian and Hispanic populations are over-sampled. Used census tracts to determine poverty. 7% of sample resided in "Inner city." Adjusted for sex but did not stratify by sex.
Ownby (2015)[10] QUANTITATIVE Georgia + Michigan, USA	Asthma prevalence among African American teenage youth in rural and urban	Cross-sectional= n=7,297 urban youth- public high schools in Detroit n=2,523 rural youth- public high schools in Georgia	Significant diff. b/t undiagnosed males in Detroit v Georgia (5.5% v 3.6% p=0.04). Detroit= inc. symptoms in the past 30 days + inc. hospitalizations but no diff. in past 12 months. Risk of asthma r/t poverty rather than urban v. rural status.	Populations surveyed 3 years apart. Self-report. Students missed + not screened. Asthma absence more likely in Detroit. No environmental data, i.e. Georgia live on farms? Only sampled public high schools.	Current asthma- Self-reported physician diagnosis + symptoms past 12 months.	African Americans broken down by females and males. All of same SES

Table 2. Physical- Outdoor Air

Author	Study	Methods	Results	Critique	Asthma	SES, Race + Ethnicity, Sex
Buonanno (2013)[16] QUANTITATIVE Italy	Health effects of airborne particle dose in children r/t respiratory health effects	Cross-sectional= n=103 children 8-11 years old. Questionnaire, exposure measures, spirometry, skin prick allergen testing. Children kept time-activity diary to record peak exposure + typical day. Carried nano-tracer for three days.	Home= major contributor to daily dose (57%). Higher exposure for females (1.75 X10^3 +/- 1.21 X10^3mm^2) than males (1.07 X10^3 +/- 5.64 X10^2 mm^2) p<0.01. Children in urban areas= particle concentrations 25% higher than the overall mean (p<0.01). No significant diff. in values in urban/rural schools or b/t males/females. Asthmatic children exposed to particulates led to increased eNO of 4.1 +/- 0.6 ppb (correlation coefficient R^2 = 0.90)	Direct assoc. b/t personal dose + respiratory health. Personal measures better than central site data.	Record respiratory symptoms with ISAAC questionnaire. "reported a diagnosis of asthma"	Equal sex distribution. No discussion of race, ethnicity or SES possibly due to sample being Italian
Glad (2012)[13] QUANTITATIVE Pittsburgh, PA, USA	Ambient Ozone (O3), PM 2.5 levels + Asthma ED visits: influence of gender and ethnicity	Case-crossover= n= 6,979 ED visits for asthma, O3 + PM 2.5	2.5% inc. in asthma ED visits for 10ppb increase in ozone level (OR=1.025 p<0.05) PM2.5 assoc. w/ total population on day 1 after exposure (p<0.05) and on African Americans on days 1, 2, and 3.	Limited air pollution monitors to measure variability across regions. ED visits not geographically representative.	ICD 9 diagnosis	Analyzed data based on age, race, + gender.
Jariwala (2011)[11] QUANTITATIVE NYC, NY, USA	Association between tree pollen and Asthma ED visits	Retrospective analysis= n= 493 # of daily asthma ED visits-7 Bronx hospitals over 1 year + daily nitrogen oxides (NOx), ozone (O3), sulfur dioxide (SO2), and pollen counts	In the fall, pediatric peak visits outnumbered adult visits. Correlation between pollen and asthma peak in the spring (r=0.9 p=0.0374)	Diagnostic (ICD codes) + geographic (large-scale data) limitations. Limited analysis for confounding	ICD 9 codes from hospital record	No data on sex, SES, or race and ethnicity
Nishimura (2013)[14] QUANTITATIVE USA	Early-life air pollution and asthma risk	Retrospective case-control= n=4,320 Children age 8-21. EPA data to calculate exposures to pollutants over the first 3 years of life.	5 ppb inc. in avg. NO2 during the first year of life was assoc. w/asthma (OR=1.17 95% CI 1.04-1.31). Region specific- asthma assoc. w/ 1st year of life exposure to PM10 = Chicago (OR=1.39 95%CI 1.04-1.86) + Puerto Rico (OR=1.25, 95% CI 1.09-1.44). Assoc. b/t SO2 in Puerto Rico (OR=1.10 95% CI 1.01-1.19). African Americans from San Fran 1st year exp. to NO2 (OR=1.43 95% CI 1.08-1.88)	Puerto Rico only has 2 monitoring stations, reducing accuracy. No personal air sampling. Unmeasured confounders-i.e. in utero exposure, birth month. Address temporality of air pollution exposures before asthma. Large area data not specific residences.	Physician diagnosed plus 2 or more symptoms	Population was Latino and African American. Similar SES due to homogenous sample. Adj. for sex but did not analyze it.

			and PM10 (OR=1.21 95% CI 1.01-1.45).			
Svendsen (2012)[15] QUANTITATIVE El Paso, Tx, USA	Traffic-related air pollutants and adverse pulmonary health	Cross-sectional= n=5,654 parent questionnaires n=1,529 spirometry tested in children in public schools. GIS modeled residential levels of air pollution (NO2) stratified by elevation.	At elevations above 1,170m a 10 ppb inc. in NO2 levels assoc. w/ current asthma (OR 1.65 95% CI 1.08-2.50). Also, NO2 (10 ppb increase) associated with 2.4% dec. in forced vital capacity (95% CI -4.0, -0.7).	Selection bias. Exposure misclassification greater among children in valley schools. Diff. in access to care in the valley. Analyzed for effect modification by indoor sources of personal exposure to NO2 (gas stoves) and SHS.	Respiratory health questionnaire and reference to "Physician's diagnosis of asthma"	Discuss sex, race and ethnicity but not necessarily SES. Analyzed results by sex.
Vierira (2012)[17] QUANTITATIVE Sao Paulo, Brazil	Urban air pollutants as risk factors for asthma	Cross-sectional= n=64 parents of children age 6-10. Individual air filters inside + outside child's home and on backpack for 30 days	NO2 (indoor air) + O3 (personal air) assoc. w/ asthma (p=0.02 for both), pneumonia (O3 p=0.02) + wheezing (p<0.01). No assoc. between outdoor NO2 and O3 and respiratory health	Small, convenient sample. Could be explained by inc. vulnerability to resp. infxn. Cross-sectional. Did not analyze all confounders. Results may be due to life-long exposure.	Parent self-report diagnosis or wheezing.	SES- sample of children living in a "poor" area. No discussion of race and ethnicity. Adj. for sex but did not analyze it.

Table 3. Physical- Outdoor Air- Traffic

Author	Study	Methods	Results	Limitations	Asthma	Sex, SES, Race + Ethnicity
Cook (2011)[18] QUANTITATIVE Perth, Western Australia	Impact of roadways on asthma severity	Spatial case-control study= n=434 Children age 0-19 over 4 years. GIS traffic exposures by measuring roads within a radius of house and their traffic counts.	150-meter radius OR=1.24 CI 1.00-1.52 (24% increase in the risk of experiencing multiple emergency contacts for asthma for every log-unit of traffic exposure)	Sample size too small to stratify by age, gender, ethnicity, or SES. Public ED records used. Limited availability of data for sex, age, SES and ethnicity. No data on other exposures. Area level classification. Assumes exposure from traffic + residential.	ICD 10 diagnosis + criteria for severe v. less severe asthma.	Did not stratify due to sample size issues.
Li (2011)[19] QUANTITATIVE Detroit, MI, USA	Asthma exacerbation + proximity of residence to major roads	Matched case-control= n=14,646 Children age 0-17	Asthma assoc. w/ proximity to primary roads (OR 0.97 95%CI 0.94-0.99) for 1 km inc. in distance. Asthma events dec. as distance b/t residence + primary road inc.. Secondary + combined (primary + secondary) not statistically significant.	Did not control for confounding of SES. Income, education due to Medicaid data. Exposure misclassification. Daily locations, indoor air quality and SHS exposure not taken into account.	ICD-9 diagnosis	Case-controls matched by gender, ethnicity, and age. Similar SES-sampled from Medicaid

Table 4. Physical- Indoor Air- Triggers and Housing

Author	Study	Methods	Results	Critique	Asthma	SES, Race + Ethnicity, Sex
Butz (2011)[21] QUANTITATIVE USA	Association b/t biomarkers + environ. measure of SHS w/ caregiver report smoking behavior and morbidity measure	Cross-sectional= n=126 children age 6-12. Baseline survey for intervention, clinical (urinary cotinine) + home environ. (nicotine sampling badges)	Children more symptom days had highest urine cotinine concentrations (not statistically significant). Data indicate a two-fold increase in urine cotinine concentrations when the caregiver was the household smoker.	Urine cotinine reflects exposure at one point in time and not long-term exposure. High risk children with asthma residing in homes with a smoker for intervention and therefore limited variance + not generalizable to non-urban children who do not live with a smoker.	Physician diagnosed asthma, symptom frequency, + use of daily controlled medication	95% African American. Discussed but did not analyze by sex. Discussed SES
Northridge (2010)[20] QUANTITATIVE NYC, NY, USA	Housing type + housing quality in urban children	Cross-sectional= n= 4,853. Children age 5-12. Parent questionnaire sent home from public schools	More asthma in public housing even after adj. (21.8% CI 17.3-26.3) Public housing more likely to have cockroaches (68.7% compared to 21%) Household with cockroaches or rats assoc. w/having current asthma in adjusted model.	Outdoor/ polluted air + psychosocial variables not measured. Those who were excluded may not have had stable residence. Cross-sectional data=no causation inference.	Parent report-physician diagnosed + wheezing in the past 12 months	Census data to determine median income (proxy for SES). African American, Puerto Rican, and children w/ low SES = greater proportions of public housing. White, Asian,+ high SES = more likely to live in private family dwellings. Sex not discussed.
Olmedo (2011)[22] QUANTITATIVE NYC, NY, USA	Exposure + sensitization to cockroach, mouse, dust mite, cat, and dog allergens	Case-control= n=403 for parent questionnaire n=248 for home visit. Children age 7-8 (dust sample + allergy test)	Assoc. between bed dust allergen conc. and sensitization for cockroach (OR 1.9 {1.6-2.4}), dust mite (OR 1.3 [1.07-1.63]), and cat (OR 1.43 [1.16-1.75]). In HAPN more cock-roach (22ng/g v 37ng/g), mouse (41ng/g v 93ng/g), and cat allergen (30ng/g v 56ng/g) and lower dust mite (10ng/g v 5.3ng/g).	Bias in phone recruitment. Possibility of unrecognized confounders. Definition of asthma was more sensitive, less specific. Only middle-income homes. Cases more likely to be black or Hispanic.	Parent report of 4 possible symptoms	HAPNs- more likely to be black or Hispanic + live in apartments. Most lived above poverty line. Not analyzed by sex. Census used to determine median income.
Martin (2013)[23] QUANTITATIVE Chicago, IL, USA	Housing related triggers among Puerto Ricans	Cross-sectional= n=101 families, child age 5-18. Baseline data for intervention study. Survey of caregiver, home assessment, salivary cotinine.	Trigger behavior summary score: 12 items. Avg. age of home was 93 years old. Majority apartments with 6 or more units. Recent construction in or near home reported by 56% of caregivers. 56% treated roaches. 33% treated for rats/mice. 43% of caregivers reported once a month or more tobacco exposure.	Results cannot be generalized. No specific allergen testing. Cotinine data showed less smoke exposure than report- but it only captures exposure over last 24 hours. Caregivers may have cleaned prior to home inspection.	Persistent or poorly controlled= measured symptoms and used ATAQ questionnaire	Self-identify as Puerto Rican. Did not discuss sex. Sample had similar SES.
Yinusa-Nyahkoon (2010)[24] QUALITATIVE Boston, MASS, USA	Ecological barriers + social forces. Qualitative analysis of	Grounded theory analysis= n=19 African American parents of children age 5-12	Four adaptive routines: give young children w/ asthma responsibility for meds, monitor availability of school nurse, manage air quality, + freq. clean the home.	Sample- not representative of "inner city" most have >high school diploma, almost half=two-parent household, all have health insurance and regular source of	Parent report of symptom frequency or Health Employer	More than half of participants lived above poverty level. Female caregivers 17 of 18. Sample was completely African American

	routines of African American families in the “inner city”	w/ persistent asthma living in the inner city. Interviews done at baseline + 1 yr. later		ambulatory care. 8 parents were unable to be contacted due to changes in phone numbers.	Data Information Set criteria	

Table 5. Social- Outdoor- Safety

Author	Study	Methods	Results	Critique	Asthma	Sex, SES, Race + Ethnicity
Coutinho (2013)[26] MIXED METHODS USA	Caregivers' perception of home + neighborhood safety r/t family asthma management	Cross-sectional= n=147 children + caregiver questionnaire, Family asthma Management systems scale (FAMSS), Cultural Stress Inventory	Ethnic group diff. by poverty F(2,140=6.29 p<0.01. Latino + African American dyads inc. chance of poverty than NLW. Diff. in perceived safety by ethnicity F(2, 124)=6.29 p<0.01. Ratings of effective family management (+) corr w/ home + neighborhood safety r=0.36 p<0.01. (-) correlated with perceived discrimination r=-0.19, p<0.05 + acculturative stress r=-.21, p<0.05.Inc. home + neighborhood safety assoc. w/ inc. optimal family asthma management F(1,114)= 5.36 p<0.05	Small sample size, cross-sectional, relied on parent report to define asthma severity. Future analysis should be done longitudinally with larger groups of urban children.	Parent report of physician diagnosed asthma	Sample was Latino, African American, and Non-Latino White (NLW). Controlled for poverty in sample. No difference in sex therefore combined male and female.
Gupta (2010)[25] QUANTITATIVE Chicago, IL, USA	Assoc. b/t community crime + asthma prevalence	Cross-sectional= n=45,371 surveys of children K-8th grade in public and catholic schools. Geocoded into 247 neighborhoods, divided into quartiles by asthma prevalence	Criminal activity was sig. higher (p<0.001) in neighborhoods with high asthma. Violent crime sig. assoc. w/ neighborhood asthma prevalence after adj. (OR 1.27 95% CI 1.04-1.55). Violence explained 15% of variation in childhood asthma p<0.05 in adj. model. Communities with higher proportion of black residents tend to have higher proportion of children with asthma p<0.001	Cross-sectional, no causality. Did not control for ambient or indoor pollutants, unreported criminal acts. Did not separate Hispanic sample to specifically Puerto Ricans. Utility in measuring crime directly.	Parent report of health care provider diagnosed asthma	Broken into 4 groups of schools; high black/mid-income, high black/low-income, low black/high-income, and low black/low-income. Did not split up Puerto Ricans. Took into account sex, SES, and Race
Vangeepuram (2012)[27] QUANTITATIVE NYC, NY, USA	Assoc. b/t parental perception of neighborhood safety + asthma diagnosis in ethnic minority urban children	Cross-sectional= n=504 parents of children age 6-8 Perception of safety questionnaire	Parents reporting feeling unsafe walking in the neighborhood were more likely to have a child diagnosed with asthma (OR=1.89 95% CI 1.13-3.14).	Cross-sectional data=no causation. May be residual confounding. Demonstrated effect of “perception” of safety rather than crime data.	Parent report of physician diagnosed asthma + 1 asthma related symptom	More females than males. Accounted for age, gender, SES, race/ethnicity, SHS and breastfeeding as child.

Table 6. Social- Indoor- Family Stress

Author	Study	Methods	Results	Critique	Asthma	Sex, SES, Race + Ethnicity
Koinis-Mitchell (2012)[28] MIXED METHODS USA	Individual, cultural + asthma-related risk + protective factors assoc. with resiliency	Cross-sectional= n=131 families, children age 6-13 From a larger study. Used Cumulative Risk Index (CRI), child's IQ, FAMSS, child asthma self-efficacy scale, Neighborhood unsafety scale, SHS.	Children below the poverty line inc. fnctnl limitation r/t those above $F(1,127)= 12.3$ $p<0.001$. Asthma functional limitation highly correlated w/ ED visits Spearman's rho =0.41 $p<0.001$. Cumulative risks assoc. w/ inc. functional limitation $r=0.25$ $p<0.01$ + risk for ED visit (past 12 months) $r=0.16$ $p<0.05$. Latinos- interaction b/t CRI and family connectedness accounted for sig. portion of variance in functional limitation R^2 = 0.23; β=-3.93, t=-2.9, $p<0.05$. Latinos- ethnic identity is a sig. resource factor in the assoc. w/ risk for ED visit (past 12 months) OR 2.8 $p<0.05$.	Sample size by ethnic group was small. Multiple comparisons were made that were not adjusted for statistical bias. Cross-sectional data. May be alternative explanations. Relied on parent report of whether child prescribed a controller medicine as proxy for asthma severity. Convenience sample. CRI was sample dependent	Self-report- physician diagnosed asthma + symptoms in past 12 months	African American, Latino, and NLW. Data analyzed by gender and SES (as main variable and contributor to CRI score)
Koinis-Mitchell (2014)[33] MIXED METHODS USA	Asthma indicators, neighborho od + family stressors	Cross-sectional= n=208 caregivers and children age 6-12. Data from 2 separate studies.	Poorly controlled asthma relates to inc. rate of neighborhood stress compared to those w/ well controlled asthma $F_{(1, 145)}= 4.5$ $p=0.04$. Similar results by ethnic group. More functional limitation d/t asthma assoc. w/ elevated levels of neighborhood + family stressors. "Family moved" was endorsed by 43% of respondents. Poor controlled children report higher level of stress r/t being afraid to go out compared to well controlled asthma $F(1,145)= 6.1$ $p=0.02$	Sample size for each ethnic group was small. Secondary data analysis of baseline data, possibly underpowered. Did analyze for all confounders- psychological symptoms, urban stress, etc. Children's stress analyzed without parent input. Relied on parent report of asthma severity. Additional research is needed to understand cumulative impact of facing several stressors and include physical neighborhood stressors.	Asthma indicators- ED visits, functional limitation (frequency of episodes, level of impairment during an attack). All had persistent asthma + symptoms in the past year.	Latino, African American, and NLW. 78% lived below poverty threshold. Analyzed by sex.
Mathilda Chiu (2012)[30] QUANTITATIVE Boston, MA, USA	Prenatal + postnatal maternal stress + wheeze in urban children	Prospective design= n=989 mothers Negative life events score (NLEs) from pregnancy to 2 years postpartum at two Boston hospitals	Children w/ mothers= high stress in both pregnancy + postpartum period were sig. more likely to have repeated wheeze (adj. OR 3.04 95% CI 1.67-5.53) compared w/ low stress in both periods. Boys were more likely to have repeated wheeze compared with girls (OR 2.28 95% CI 1.34-3.88).	Maternal-reported wheeze as surrogate for developing asthma. Mother's with higher stress might under-report child's symptoms (if this is true, then results were underestimated). Higher stress might over-report symptoms (but results align with previous studies). Accounted for infant sex and season of birth. Demonstrated temporality of assoc.	Measured child wheeze from birth to age 2 years through interviews at 3-month intervals.	Took into account race and ethnicity, education and income. Mothers were primarily Hispanic (55%) and African American (29%) and low SES (62% having ≤12 yr. of education)
Otsuki (2010)[31]	Maternal depressive	Prospective design=	Time1 caregiver depressive symptoms predicted Time2 child asthma	Participants recruited high asthma morbidity, therefore ED visits may not be	Asthma morbidity= # of	African American sample of mothers.

QUANTITATIVE Baltimore, MD, USA	symptoms + asthma morbidity	n=262 African American mothers of children Secondary data. Survey (CES-D) at baseline and 6 months later.	symptoms (B=0.15, $p<0.01$), maternal depressive symptoms did not predict child asthma ED visits. Child's asthma was not demonstrated to influence caregiver's mental health over time.	best outcome measure. Reliance on mother of self-report of asthma symptoms, ED visits, and depressive symptoms. Used only 2 time points. Solely African American sample, therefore cannot generalize. Prospective data demonstrates directionality.	symptoms per month. Severity- daytime + nighttime frequency. ED visits in past 6 months.	Gender and income discussed. Primarily low SES sample.
Sampson (2013)_ MIXED METHODS Detroit, MI, USA	Conceptualizations of caregiver stress among low-income families of children with asthma	n=40 Families- qualitative semi-structured interviews (saturation reached) and quantitative surveys Zarit burden caregiver scale and PedsQL Family Impact Module, CES-D.	Financial uncertainties=chronic stressors. Combined stressors are interactive. Stress is highly correlated with depression. "I wouldn't look at it as stress" theme implies that stress scales may not appropriately assess caregiver stress r/t asthma. Caregivers reported high stress r/t: asthma-related change, uncertainty, control and anxiety, but did not associate this stress with their child. Single parents reported slightly lower QOL, inc. depression, lower income + more chronic illness (not stat sig due to small sample)	Caregivers who did not participate may have had additional obligations and stressors that were not captured. Possible social desirability bias when interviewed. Continue to validate stress-related scales among low-income families. Mixed-method approach useful to investigate discrepancy b/t quantitative stress response and qualitative discussion of stress, illustrated differing views of concepts from caregivers.	Asthma diagnosed by health professional (89.5%), taken doctor-prescribed medications, inhalers, or nebs (90%)	37 of participants were female. Primarily identified as African American (80%). Median income significantly below federal poverty line. Did not assess role of race +ethnicity as participants were all of one race.
Quinn (2010)_ QUANTITATIVE Chicago, IL, USA	Parent perceptions of neighborhood stressors associated with child respiratory health among low-income urban families	Cross sectional= n=319 parents of children 5-13 Parents' perceptions of neighborhoods + respiratory health= collective efficacy (CE) and physical/social order (Order)	Parent health strongly associated with CE ($RD_{low\ v\ high}$ 20.8 95% CI 7.8-33.9) and order ($RD_{mid\ v\ high}$ 11.4 95% CI 2.1-20.7). Waking at night assoc. with CE ($RD_{low\ v\ high}$ 16.7 95% CI 2.8-30.6) and order ($RD_{low\ v\ high}$ 22.2 95% CI 8.6-35.8). General health outcomes associated with collective efficacy, child respiratory outcomes more associated with order.	Outcomes coded as binary rather than ordinal. Selection bias. Cross-sectional + limited to one city=did not incorporate all risk factors or test causation. No biological or behavioral risk factors. Reverse causality because stress may be aggravated by having asthma. Neighborhood collective efficacy affects parents more than kids because they are not concerned with larger environment.	Asthma diagnosis + symptom questions	75% of enrollment qualified as low-income. More than half were Hispanic, 1/3 non-Hispanic black, and 12% non-Hispanic white. Controlled for sex but did not analyze it. 93.4 % of parents were female.

MANUSCRIPT TWO: The relationship between neighborhood safety and children's asthma: An integrative review

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Abstract

Background- There is a growing body of research analyzing relationships between neighborhood safety and children's asthma prevalence and control. There are several inconsistencies in concepts and methods that have led to mixed results.

Purpose- The purpose of this review is to critically evaluate the current evidence analyzing neighborhood safety and childhood asthma and identify nursing research and policy implications.

Methods- An integrative review was conducted by searching PubMed, CINAHL, EMBASE, and PsychINFO databases to identify peer-reviewed articles published between 2010-2017. Fourteen studies met inclusion criteria.

Findings- Overall, there was evidence pointing to associations among neighborhoods being unsafe and higher asthma prevalence and/or poorer asthma control.

Conclusions- The association between neighborhood safety and children's asthma warrants further research with universal definitions for neighborhood safety and multi-level modelling. The review also supports the "health in all policies" approach as safety is one of several social determinants of health, that influence children's asthma.

Keywords: integrative review; asthma; neighborhood safety; social determinants of health

Introduction

Could unsafe neighborhoods influence children's asthma? Theoretically, yes. Unsafe neighborhoods present a chronically stressful environment that is thought to influence asthma through two pathways. First, parents in unsafe neighborhoods are more likely to keep their children indoors,[1] limiting physical activity and resulting in increased exposure to indoor allergens and pollutants, including second hand smoke.[2] Secondhand smoke not only exacerbates existing asthma by irritating the small airway epithelium,[3] but it is hypothesized that exposure early in childhood may increase the risk of acquiring asthma.[4,5]

The second pathway is the inflammatory effect of stress on asthma. Children with asthma who experience chronic stress have a heightened inflammatory profile that puts them at greater risk for asthma exacerbations.[6] Lower socioeconomic status is also associated with higher chronic stress as well as increased production of inflammatory markers.[6] It has been hypothesized by many researchers that chronic stress, such as that caused by living in an unsafe neighborhood, is the strongest mechanism through which poverty exerts its effects on children's health.[7-9]

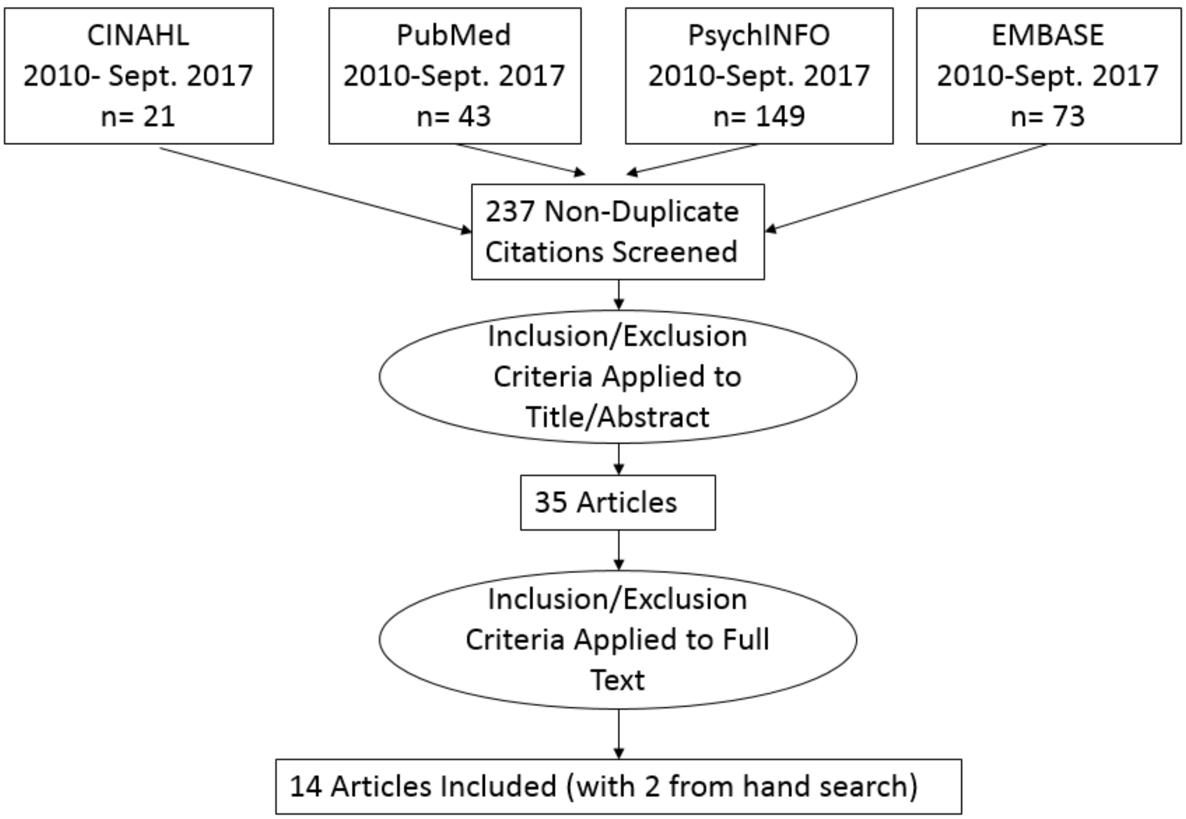
Currently 6.3 million children in the United States have asthma,[10] a complex illness characterized by chronic inflammation of the airways. Asthma is associated with a decrease in children's quality of life and high healthcare expenditures. It is estimated that asthma (for adults and children) costs the United States $81.9 billion annually in expenditures incurred by absenteeism, mortality, and health care.[11] Asthma disproportionately affects racial and ethnic minorities and children living in poverty.[10,12] One study found that African American children have a population-based risk of asthma-related death rate that is 7.1 times higher than non-Hispanic white children (population-based risk [PBR] 7.1, 95% confidence interval [CI] 5.2-

9.7).[12] Several factors including neighborhood safety have been proposed to be associated with poorer asthma control especially in low income children. Research into relationships between neighborhood safety and children's asthma might inform interventions aimed at decreasing health disparities in children's asthma. This research might also support a Health in All Policies (HiAP) approach whereby, child health outcomes are incorporated into discussions and policy regarding safety. The purpose of this integrative review was to critically evaluate the current evidence focusing on neighborhood safety and childhood asthma and to identify nursing research and policy implications.

Methods

We followed steps proposed by Whittemore and Knafl to conduct this review which include problem identification, performing the literature search, then evaluating, analyzing, and presenting the data.[13] The literature search was conducted in September 2017 using CINAHL, Pubmed, PsychINFO, and EMBASE databases. The search terms were developed by the authors with the assistance of a medical librarian and included the following: environment, social environment, residence characteristics, neighborhood, safety, crime, exposure to violence, child, infant, toddler, and adolescent. The search term "asthma" was used for the outcome variable. The Pubmed search strategy can be found in Appendix A. The search process diagram (Figure 1) illustrates the article selection process. Inclusion criteria include articles that were: full text, peer-reviewed, English language, and published after January 1st, 2010 in order to provide the most up-to-date research. Exclusion criteria included articles: without asthma as the outcome, focusing on adult asthma, and those focusing on exposure to intimate partner violence. After the title and abstract screen, we found 35 articles warranting a full text screen. The remaining studies were read completely, and studies based on adult asthma (n=3), exposure to intimate partner violence (n=11), primary outcomes other than asthma (n=4), and review articles (n=5) were excluded. Out of the 35 articles 12 met the inclusion criteria. Two additional articles were added after hand searching the reference lists of the original 12 articles. There were no restrictions on primary author discipline, location of the study, or methodological orientation. The data extracted from each study included the location, sample size, study design, target populations, primary outcome, measurement of variables, and findings. Data were placed in a table and critically analyzed for convergence of research and potential limitations.

Figure 1. Search Process Diagram



Results

Study characteristics

Table 1 contains detailed, extracted information from each article.

Table 1. Studies on Neighborhood Safety and Children's Asthma

Author	Purpose	Study design and sampling	Sample	Measurement			Main findings
				Asthma	Neighborhood	Safety	
Gupta (2010)[14] Chicago, IL	Association between community crime and asthma prevalence.	Cross-sectional; N=45,371 surveys of children K-8th grade in public and catholic schools geocoded into 247 neighborhoods	4 groups of schools based on % of black students and income. Did not account for Puerto Rican ethnicity.	Parent report of health care provider diagnosed asthma	Neighborhoods defined by police beat	Crime statistics from Chicago Police Department	Criminal activity significantly higher ($p<0.001$) in neighborhoods with high asthma prevalence. Violent crime significantly associated w/ neighborhood asthma prevalence after adjustment (aOR 1.27; 95%CI 1.04-1.55). Violence explained 15% of variation in childhood asthma $p<0.05$.
Sternthal (2010)[15] Chicago, IL, USA	Association between community violence exposure and childhood asthma risk	Longitudinal study; N=2,071 caregivers of children (0-9 years old at enrollment) within 80 neighborhood clusters	Children-African American (34.1%) and Mexican (32.1%). Caregiver's education and income were included	Caregivers asked if their child had ever been diagnosed with asthma or if they took asthma medications	80 Neighborhood clusters	Caregiver filled out "My Exposure to Violence survey"	Medium (aOR 1.60; 95% CI 1.17-2.19) or high (aOR 1.56; 95%CI 1.12-2.18) levels of community violence were associated with increased asthma risk compared to low levels.
Shankardass (2011)[16] Southern California, USA	Associations with crime and asthma	Longitudinal (over 3 years) N=2,456 children (5-9 years old at baseline) within 274 census tracts, within 45 schools within 13 communities	Majority of children were Hispanic (55.3%) or non-Hispanic White (36.2%). Low parental education was reported for 21.1% of subjects and 55.1% had medium education.	New onset asthma asked parent over the three years if the child was diagnosed by a physician with asthma	Hierarchical data in community (Crime in this level), schools, neighborhoods (census tract), and individuals	Larceny (theft involving taking of personal property) crime rate calculated using policy department data	Increased risk for asthma for children residing in communities with higher rates of larceny crimes (adjusted hazard ratio 2.02, 95%CI 1.08-3.02).
Alves (2012)[17] Salvador, Bahia State, Brazil	Association between degrees of exposure to community violence and	Cross-sectional; N=1,232 parents of children (4-12 years old) in 24 neighborhoods	51.1% of sample had family incomes of one month minimum wage or less (proxy for SES). No	Wheezing in past 12 months and lifetime asthma, wheezing during exercise, ≥4 episodes of	"Micro-areas" in peripheral neighborhoods in Salvador, the capital of	Degree of exposure to violence (questionnaire)	Children exposed to more violence have higher asthma prevalence (28.4%) than those not exposed (16.4%). Children exposed to maximum levels more likely to have asthma symptoms than those not exposed (aOR=1.94; 95%CI:1.12-3.36)

	child asthma prevalence		discussion of race or ethnicity	wheezing in last year, waking once a week at night	Bahia State, Brazil		
Vangeepuram (2012)[18] New York City, NY, USA	Association between parental perception of neighborhood safety and asthma diagnosis	Cross-sectional; N=504 parents of children (6-8 years old)	Sample primarily Hispanic (73.5%) and non-Hispanic Black (26.5%). Annual income <$25,000 (54%)	Parent report of physician diagnosed asthma + 1 asthma related symptom	No analysis by neighborhood	8 item version of "Things I have Seen and Heard" questionnaire	Parents reporting feeling unsafe walking in the neighborhood were more likely to have a child diagnosed with asthma (OR 1.89; 95% CI 1.13-3.14)
Hellyer (2013)[19] Colorado, USA	Association between maternal and community risk factors and asthma	Cross-sectional; N=365 children (9-11 years old) in foster care	Sample was Hispanic (51.5%), Black (26.8%), and Caucasian (50.7%): non-exclusive categories. No measure of SES in analysis.	Child or caregiver report of asthma (some of the children spent less than 2 months living with their caregiver which justified this method)	No analysis by neighborhood	8 item version of "Things I have Seen and Heard" questionnaire	After controlling for demographic variables maternal risk was associated with asthma but community violence exposure was not related to the presence of asthma.
Bellin (2014)[20] Baltimore, MD, USA	Examine longitudinal effects of parent exposure to community violence (ECV) on asthma morbidity	Longitudinal, secondary data analysis; N=300 parents of children (3-10 years old)	Children were predominantly African American (96%) and caregivers were predominantly low income (50% earned less than $10,000 per year).	Asthma control developed based on NAEPP guidelines accounting for symptom days/nights, activity limitations, rescue inhaler use, ED visits + hospitalizations.	No analysis by neighborhood	Caregiver filled out the "Safety in Community" sub-scale from the "Crisis in Family Systems" scale	Caregiver ECV predicted asthma-related healthcare utilization at baseline (b=0.19, SE=0.07, p=0.003) and 2 months (b=0.12, SE=0.05, p=0.04).
Camacho-Rivera (2014)[21] Los Angeles, CA, USA	Associations between measures of neighborhood safety, individual and family characteristics, and child's	Cross-sectional; N=3,114 children (0-17 years old) in 65 neighborhoods	Caregiver's health insurance, education and use of public assistance. Sample predominantly "Hispanic" (64%).	Caregiver report of asthma diagnosis	Census tracts are referred to as neighborhoods	Parent filled out perceived neighborhood safety questionnaire consisting of 3 questions	Parents who reported their neighborhood as fairly safe or somewhat dangerous (walking at night) had lower odds of asthma compared to those who reported their neighborhood as completely safe (OR 0.71; 95%CI 0.52-0.96 and OR 0.60; 95%CI 0.42-0.88 respectively). Parents who could not trust their neighbors to watch out for their child had a 39% increase in asthma compared to those who trusted their neighbors (OR 1.39; 95%CI 1.07-1.81).

	asthma outcomes.						
Koinis-Mitchell (2014)[22] RI, USA	Associations between neighborhood and family stressors and asthma indicators for urban living children	Cross-sectional; N=208 urban children with asthma (6-12 years old) and their primary caregivers	Sample was 55.3% Latino, 22.1% Black/African American, 22.6% Non-Latino White. 57.2% of the sample lived below the poverty threshold.	Asthma Control Test to determine asthma control, used functional limitation and ED visits in the past year- all assessed by caregiver	No analysis by neighborhood	Children's perception of neighborhood and family stressors assessed with 23-item instrument designed to capture neighborhood disadvantage and family/life transitions	Children with poorly controlled asthma reported a higher rate of neighborhood stress (M=12.8 SD=8.3) compared to children with well controlled asthma (M=9.8 SD=7.3), $F(1,145)= 4.5$ $p=0.04$. Children in poor control reported a higher level of experienced stress related to being afraid to go out (M=0.85 SD= 1.2) compared to children with well controlled asthma (M=0.42, SD=0.8), $F(1,145)= 6.1$, $p=0.02$.
Kopel (2015)[23] Boston, MA, USA	Association between caregiver perception of neighborhood safety and asthma morbidity	Cross-sectional; N=219 caregivers of children (5-15 years old)	Predominantly Black (40.2%) and household income < $25,000 annually (45.3%)	Asthma control defined based on NAEPP guidelines taking into account symptom days/nights, activity limitation and rescue inhaler use,	No analysis by neighborhood	Caregiver perception of safety assessed by asking one question-"Is it safe to walk alone in the neighborhood at night?"	Children whose primary caregivers perceived the neighborhood to be unsafe had twice the odds of having poorly controlled asthma (aOR 2.2; 95%CI1.2-3.9) four times the odds of dyspnea and rescue medication use (aOR 4.7; 95%CI 1.7-13.0 and aOR 4.0; 95%CI 1.8-8.8, respectively), three times as much activity limitation (aOR 3.2; 95%CI1.4-7.7) and more than twice the odds of nighttime symptoms (aOR 2.2; 95%CI1.3-4.0) compared to participants living in safe neighborhoods.
Ramratnam (2015)[24] San Juan, PR, USA	Association between exposure to gun violence and childhood asthma	Cross-Sectional; Case-Control; N=466 children (9-14 years old)	Children were all Puerto Rican. Predominantly low-income with annual income <$15,000 (61.3%)	Physician diagnosed asthma and wheeze in the prior year	No analysis by neighborhood	Children asked how many times they had heard a gunshot in their lifetime and if they were afraid to leave their home because of violence	Children with asthma were more likely to have heard a gunshot more than once compared to control subjects (n=156 or 67.2% vs. n=122 or 52.1% $p<0.01$). In multivariable analysis, hearing a gunshot more than once was associated with asthma (OR 1.8; 95%CI1.1-1.7). Children who had heard at least one gunshot and were afraid to leave their home had 3.2 times greater odds of asthma compared to those children who had not heard a gunshot and were not scared to leave their homes (OR 3.2; 95%CI 2.2-4.4).

Beck (2016)[25] Cincinnati, OH, USA	Association between population-level crime (violent and all-crime) rates and population-level child asthma control	Retrospective Cohort-Study; N=4,638 children (2-17 years old) in 104 census tracts	Poverty rate from American Communities Survey, Insurance for individual used as marker for SES. Predominantly African American sample (83%).	Utilization rate calculated by dividing ED and hospitalization events for asthma by total number of children age 2-17 in census tract	Census tract level data	Violent crime rate and all crime rate from Cincinnati Police Department data from Jan. 2011-Dec. 2013	Census tract-level violent and all crime rates significantly correlated with asthma utilization after adjustment for census tract poverty, unemployment, substandard housing, and traffic exposure (p=0.002, p=0.02 respectively). Violent crime rate explained 35% of population-level asthma utilization variance and all crime rate explained 28%.
Eldeirawi (2016)[26] Chicago, IL, USA	Association between neighborhood crime and asthma and asthma morbidity for Mexican American Children	Cross-sectional; N= 2,023 parents of Mexican American children (mean age 10 years old) in Chicago	Children were Mexican American, 45.5% were born in Mexico, no data on individual SES but across neighborhoods in study 17.6% of families lived below the federal poverty line	Parent asked if child had-Physician diagnosed asthma, respiratory symptoms (current and ever) and ED visits or hospitalization due to asthma	Census tract level data	Chicago Police Department data on violent, property and drug abuse crime	A 1 SD increase in property crime significantly increased the odds of lifetime asthma, lifetime wheezing, lifetime ED visits due to asthma, and hospitalization due to asthma (25%, 18%, 44%, and 62% respectively). A 1 SD increase in violent crime was positively associated with higher odds of lifetime wheezing and ED visits (21% and 57% respectively). For a 1SD increase in drug abuse crime there were increased odds of lifetime wheezing and ED visits (13% and 44% respectively).
Yakubovich (2016)[27] South Africa	Association between socioeconomic factors and childhood asthma	Cross-sectional; N=6,002 children (10-17 years old) from 6 sites in three South African provinces	SES addressed by asking "number of unavailable necessities" + "number of employed people in household." No discussion of race or ethnicity.	"In the past year, have you had asthma?" (measure checked by symptom corroboration and caregiver and child report triangulation)	Incorporated province into analysis.	Child Exposure to Community Violence Checklist	Community violence associated with increased odds of having asthma (OR 1.14; 95%CI 1.00-1.30)

Measurement of asthma and exposure variables

In this integrative review, we used asthma as the primary outcome and neighborhood safety as the exposure variable. The operationalization of asthma varied throughout each study. A majority of the studies (ten out of fourteen) used parent or child report of asthma diagnosis as the primary outcome variable. The remaining four of the fourteen studies used asthma control as the primary outcome. Kopel et al[23] and Bellin et al[20] calculated asthma control based on national guidelines from the National Asthma Education and Prevention Panel Expert Panel Report [28]. These guidelines are the primary resource for health care providers, developed by experts working through the National Heart Lung and Blood Institute of the National Institutes of Health (NIH), they present a universal method for diagnosis and treatment of asthma and therefore present a clinically relevant method for operationalizing asthma severity and control. Koinis-Mitchell et al used the Asthma Control Test questionnaire as well as information regarding functional limitations and ED visits.[22] The final study[25] used the International Classification of Diseases (9th revision) codes to determine asthma emergency department and hospitalization events.

Four of the fourteen articles assessed perceived neighborhood safety using a questionnaire asking the child or the child's primary caregiver whether or not their neighborhood was safe.[18,21-23] In a large study (N=3,114) of Latino parents, parents were asked "How safe it is to walk alone at night?" and whether or not this parent could trust adults in the neighborhood to watch whether children are safe.[21] Another study by Kopel et al asked caregivers (n=219) one question, "is it safe to walk alone in the neighborhood at night?"[23] The third study used six yes/no questions asking parents (n=504) about neighborhood elements including sidewalk condition, perceived child safety while walking, and safety from crime.[18] The fourth study (n=208) used a 23-item instrument to assess the child's perception of neighborhood stressors.[22]

Four of the fourteen studies used a questionnaire regarding exposure to violence reported by the child.[17,19,24,27] Two longitudinal studies focused on parent reports of children's exposure to violence assessing risk for asthma diagnosis [15] and risk for asthma-related ED visits.[20] Four of the fourteen articles measured community or population-level crime using police reported crime data.[14,16,25,26]

Association between neighborhood safety and children's asthma prevalence

Overall, the studies demonstrated that living in an unsafe area is associated with higher asthma prevalence, but there were some discrepancies reported. If caregivers perceived the neighborhood to be unsafe, their children had a higher asthma prevalence (OR 1.89, 95% CI 1.13-3.14) [18] as compared to children of caregivers who perceived their neighborhoods to be safe. Camacho-Rivera et al found that parents who felt their neighborhood was fairly safe or somewhat dangerous (in regard to walking alone at night) had lower asthma prevalence compared to those who reported their neighborhood as completely safe (odds ratio [OR] 0.71, 95% confidence interval [CI] 0.52-0.96 and OR 0.60, 95% CI 0.42-0.88, respectively).[21] A contradictory finding from this same study found that parents who reported they could not trust their neighbors to keep their child safe had a 40% increase in their child's lifetime asthma prevalence compared to those who could trust their neighbors (OR 1.39, 95% CI 1.07-1.81). One possible explanation for this discrepancy is that the researchers only used two questions to assess neighborhood safety and they address different concepts; "feeling safe to walk at night" captures safety while "trusting adults in the neighborhood to watch out for children" focuses on collective efficacy, defined as mutual trust between neighbors and a willingness to intervene on behalf of the common good.[29]

In general, the studies utilizing children's report of exposure to violence all demonstrated that increasing violence is associated with higher asthma prevalence. One conflicting finding by Hellyer, Garrido, Petrenko & Taussig reported that there was no relationship between community violence exposure and asthma prevalence among 9 to 11-year-old children (n=365) in foster care in the United States.[19] The researchers hypothesized that because these children are at increased risk for chronic diseases the effects of violence may not be as obvious for this sample.[19] Two of the articles used an "Exposure to Community Violence" questionnaire and found a higher asthma prevalence for children exposed to more community violence for 6,002 children in South Africa (OR=1.14, 95% CI=1.00-1.30) [27] and 1,232 children in Brazil (asthma prevalence 28.4% for those exposure to violence and 16.4% to those not exposed to violence).[17] Similarly, Ramratnam and colleagues found that children with asthma were more likely to have heard a gunshot more than once compared to non-asthmatic children (67.2% versus 52.1%, $p<0.01$, n=466 total).[24] This study also reported that children who had heard at least one gunshot and were afraid to leave their homes had 3.2 times greater odds of asthma compared to children who had not heard a gunshot and were not scared to leave their homes (OR 3.2, 95% CI 2.2-4.4).[24]

Research on parent reports of children's exposure to violence comes from a longitudinal study assessing risk for asthma.[15] Sternthal, Jun, Earls, and Wright found that in their sample of inner-city caregivers (n=2,071) of children from Chicago, medium (aOR 1.60, 95% CI 1.17-2.19) and high (aOR 1.56, 95% CI 1.12-2.18) levels of community violence were associated with increased asthma risk compared to low levels of violence.[15]

Studies using police reported crime data found that higher crime rates are associated with increased asthma prevalence and asthma ED visits. Using a sample of 45,371 children in kindergarten through 8th grade, Gupta et al demonstrated that in Chicago, violent crime is significantly associated with asthma prevalence after adjusting for community race and socioeconomic status when defining neighborhoods by police beat (aOR 1.27, 95% CI 1.04-1.55).[14] Shankardass et al in Southern California analyzed data from 2,456 children and found an increased risk for asthma in children residing in areas with high rates of larceny crimes compared to children living in areas with lower rates of larceny (adjusted hazard ratio=2.02, 95% CI= 1.08-3.02).[16] In Chicago, Eldeirawi and colleagues analyzed a sample of Mexican American children (n=2,023) and found that property crime, but not violent crime or drug abuse crime, was associated with higher asthma prevalence (aOR=1.25, 95% CI= 1.07-1.46) and that property crime, violent crime, and drug abuse crime were associated with increased ED visits for asthma (aOR=1.44, 95% CI= 1.05-1.96; aOR=1.57, 95% CI= 1.16-2.12; aOR= 1.44, 95% CI= 1.17-1.78, respectively).[26] Based on this review, unsafe neighborhoods appear to be associated with increased asthma prevalence.

Association between neighborhood safety and children's asthma control

In predominantly cross-sectional research there is evidence that unsafe areas are associated with poorer asthma control. Kopel et al found that if caregivers perceived the neighborhood to be unsafe, their children had higher odds of uncontrolled asthma (adjusted odds ratio [aOR] 2.2, 95% CI 1.2-3.9).[23] Koinis-Mitchell et al found that children with poorly controlled asthma reported a higher rate of neighborhood stress [$F(1, 145)=4.5$, $p=0.04$)] compared to those with well controlled asthma.[22] This study also found that children with poor asthma control were more likely to be scared to go outside in their neighborhoods compared to children with well controlled asthma [$F(1,145)=6.1$, $p=0.02$)].[22] The longitudinal analysis by Bellin et al measured caregiver's (n=300) report of exposure to community violence in Baltimore finding that caregiver exposure to community violence predicted asthma-related ED visits at baseline (ƅ=0.19, $p=0.03$) and 2 months later (ƅ =0.12, $p=0.04$).[20] Beck et al analyzed census tract-level violent and all crime rates for Cincinnati and found that after adjustment for census tract poverty, unemployment, substandard housing and traffic exposure, violent crime rate ($p=0.002$) and all crime rate ($p=0.02$) were significantly associated with 4,638 children's emergency department (ED) visits for asthma exacerbation.[25] There are fewer studies on asthma control than prevalence, but this review found a trend indicating that unsafe neighborhoods are associated with poorer asthma control.

Discussion

Overall, there is evidence that unsafe neighborhoods (as reported by parents/children or demonstrated by violent crime statistics) are associated with higher asthma prevalence and poorer asthma control. The two longitudinal studies that were included presented evidence that community violence increases risk for asthma in children[15] and predicts asthma-related healthcare utilization.[20]

Measurement of Neighborhood

Although "neighborhoods" were conceptually defined the same, they were operationalized in varying ways. Six of the fourteen studies did not incorporate neighborhoods in their analyses.[18-20,22-24] The safety measurement for these six studies included the terms "community" or "neighborhood" and asked participants to think of their own neighborhood during data collection. One downfall of this approach is that statistical analysis is one level so there is no way to account for clustering of data across neighborhoods. Measures of neighborhood were diverse and included police beat,[14] neighborhood clusters and provinces,[15,17,27] and census tracts.[16,21,25,26] Of those who measured based on neighborhood, all eight articles used multi-level modelling in their statistical analysis to allow for correlations between neighborhood and individual level variables[31] suggesting that rigorous neighborhood level research requires multi-level modelling for appropriate data analysis.

Measurement of "Safety"

Neighborhood safety was operationalized several different ways. Some articles asked about safety, others assessed exposure to community violence, and some used neighborhood level crime rates as an objective measurement of exposure to community violence. All of these definitions attempted to capture similar, yet distinct elements of neighborhood safety. Measuring population level crime rates might be one way to account for the toxic exposures present in neighborhoods. Looking at a more proximal marker of safety, perceived neighborhood safety (or violence) represents individual perceptions of neighborhoods that guide behavior. For example, Kopel et al[23] had a relatively homogenous group geographically but there were large differences in perception of safety amongst caregivers; those who perceived the neighborhood as unsafe were more likely to have a child with poorly controlled asthma. Therefore, the subjective perception of safety, not the objective neighborhood safety, was associated with asthma control. Comparison between objective and subjective perceptions regarding the respondents' view of neighborhood safety will yield insights into the relationship.

In a sample of adolescents, perceived neighborhood violence was associated with psychological distress but there was no relationship between objective neighborhood violence and psychological distress.[32] Although the outcome variable was psychological distress, rather than asthma prevalence, neighborhood violence is thought to affect children with asthma through the stress pathway, so this finding might translate to increased asthma prevalence and exacerbations.

Measurement of Asthma

Similar to the measurement of independent variables, there were inconsistencies with how to measure asthma and asthma control that lead to difficulty interpreting results. One limitation of several studies assessing asthma prevalence was that the data was based on parent report of an asthma diagnosis in their child. This may result in an underestimate of asthma prevalence if children have not received health care or been diagnosed with asthma. This type of misclassification of asthma cases would most likely bias results toward the null so it is less of a concern. When reviewing measures for asthma control, several studies used "ED visits" as a proxy for poor asthma control as well as calculating asthma control based on provider guidelines. Both methods have merit depending on goals of the study. Increased ED visits are associated with increased healthcare costs, poorer quality of life, and children who are at the greatest risk for life-threatening asthma.[33] Calculating asthma control based on the NAEPP Expert Panel Guidelines is standard as this calculation is done by health care providers based on objective and subjective factors to inform decisions for asthma medication management.[28] While neither method is superior the implications of results vary and should be interpreted within the context of the reported study.

Limitations

Potential review limitations are based on choices made during the literature search. Exclusion of older applicable studies may have been excluded and is a possible limitation of the inclusion criteria to include articles from 2010 to September 2017. This time frame was justified due to frequent advances in the asthma field. There is also a chance that the search terms were not broad enough to capture all possible articles. In order to prevent this issue a medical librarian was consulted to develop the search strategy. MeSH terms and search terms were used in order to broaden the search and err on the conservative. Although there are potential limitations, this review uniquely contributes to the growing literature on neighborhood-level factors associated with children's health.

Implications for Nursing Research

This review supports a recent recommendation put forth by a Robert Wood Johnson Foundation (RWJF) white paper encouraging nurse researchers to investigate how social environments affect health outcomes.[34] In order to build population health, nurses must integrate research on relationships linking social determinants to health and begin testing interventions to improve health. The findings of this review demonstrate a need for a universal direction in research on asthma and neighborhood safety. By using one universal definition for neighborhood safety, future research can be compared through meta-analysis to draw stronger conclusions and advance science in this area.

This review has also illuminated a gap for nursing research going forward. Out of all the articles, there was no research analyzing both perceived neighborhood safety (subjective) and an objective measure of neighborhood safety (such as neighborhood violent crime rates) within the same study. This would allow the two measures to be compared to determine which has a stronger association with asthma. This research has the potential to inform interventions aimed at decreasing racial, ethnic, and socioeconomic health disparities in children's asthma.

Policy Implications

This research, as part of a concerted effort to investigate specific social determinants of health, demonstrates that unsafe neighborhoods may negatively impact children's health. While safety and health may be thought of as two different entities, it is clear that policy in one area will affect the other. Therefore, this review supports the Health in All Policies (HiAP) approach. The goal of HiAP is to link all public policies across sectors to (a) systematically assess the health impacts of policies, (b) seek collaborations, and (c) avoid harmful health impacts.[35] Through HiAP, sectors that were not previously thought of as "health-related" such as safety, would collaborate with health professionals to conduct health impact assessments before implementing additional policies.

As was recommended by the RWJF white paper, nurses should "advocate for funding for population-focused nursing education and research."[34] Not only would funding support current research, it would also support nurses to develop and test interventions to improve population health across the life course.

Conclusion

The safety of the neighborhood is one social determinant of health that is associated with the high prevalence and burden of asthma in children. Further nursing investigation into this area is warranted to understand relationships and inform future intervention research. Promoting a Health in All Policies approach is one step that acknowledges the impact of social determinants on health. In addition, nurses should continue to advocate for funding to support population-focused nursing research. Neighborhood safety deserves further investigation as it is one research area where nursing researchers might intervene to work to achieve health equity for children with asthma.

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References

1. Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: Evidence from a national longitudinal study. *American Journal of Epidemiology*. 2013:kws353.
2. Kanchongkittiphon W, Mendell MJ, Gaffin JM, Wang G, Phipatanakul W. Indoor environmental exposures and exacerbation of asthma: An update to the 2000 review by the institute of medicine. . 2015;123(1):6. http://nrs.harvard.edu/urn-3:HUL.InstRepos:13890681.
3. Lang JE, Dozor AJ, Holbrook JT, et al. Biologic mechanisms of environmental tobacco smoke in children with poorly controlled asthma: Results from a multicenter clinical trial. *Journal of Allergy and Clinical Immunology: In Practice*. 2013;1(2):172-180.
4. Silvestri M, Franchi S, Pistorio A, Petecchia L, Rusconi F. Smoke exposure, wheezing, and asthma development: A systematic review and meta-analysis in unselected birth cohorts. *Pediatric Pulmonology*. 2015;50(4):353-362. https://onlinelibrary.wiley.com/doi/abs/10.1002/ppul.23037. doi: 10.1002/ppul.23037.
5. O'Connor GT, Cynthia M Visness, Lynch SV, et al. Early-life home environment and risk of asthma among inner-city children. *Journal of Allergy and Clinical Immunology*. 2018;141(4):1468. https://search.proquest.com/docview/2021692519. doi: 10.1016/j.jaci.2017.06.040.
6. Marin TJ, Chen E, Munch JA, Miller GE. Double-exposure to acute stress and chronic family stress is associated with immune changes in children with asthma. *Psychosomatic Medicine*. 2009;71(4):378-384. http://www.ncbi.nlm.nih.gov/pubmed/19196805. doi: 10.1097/PSY.0b013e318199dbc3.
7. Wise PH. Child poverty and the promise of human capacity: Childhood as a foundation for healthy aging. *Academic Pediatrics*. 2016;16(3):S45. http://www.sciencedirect.com/science/article/pii/S1876285916000309. doi: 10.1016/j.acap.2016.01.014.
8. Schreier HMC, Chen E. Socioeconomic status and the health of youth: A multilevel, multidomain approach to conceptualizing pathways. *Psychological bulletin*. 2013;139(3):606-654. http://www.ncbi.nlm.nih.gov/pubmed/22845752. doi: 10.1037/a0029416.
9. Wadsworth M, Rienks S. Stress as a mechanism of poverty's ill effects on children. making a case for family strengthening interventions that counteract poverty-related stress. *CYF News, Special Edition on Poverty, Health Disparities, and the Nation's Children*. 2012.
10. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. National center for health statistics (2014). . 2014.
11. Nurmagambetov T, Kuwahara R, Garbe P. The economic burden of asthma in the United States, 2008–2013. *Annals of the American Thoracic Society*. 2018;15(3):348-356. https://search.proquest.com/docview/2021667795. doi: 10.1513/AnnalsATS.201703-259OC.

12. Zahran H, Bailey C, Damon S, Garbe P, Breysse P. Vital signs: Asthma in children - United States, 2001-2016. *US Department of Health and Human Services/Centers for Disease Control and Prevention*. 2018:149-155.
13. Whittemore R, Knafl K. The integrative review: Updated methodology. *Journal of Advanced Nursing*. 2005;52(5):546-553. http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2648.2005.03621.x/abstract. doi: 10.1111/j.1365-2648.2005.03621.x.
14. Gupta RS, Zhang X, Springston EE, et al. The association between community crime and childhood asthma prevalence in Chicago. *Annals of Allergy, Asthma & Immunology*. 2010;104(4):299-306. http://www.sciencedirect.com/science/article/pii/S1081120609000507. doi: 10.1016/j.anai.2009.11.047.
15. Sternthal MJ, Jun HJ, Earls F, Wright RJ. Community violence and urban childhood asthma: A multilevel analysis. *Eur Respir J*. 2010;36(6):1400-1409.
16. Shankardass K, Jerrett M, Milam J, Richardson J, Berhane K, McConnell R. Social environment and asthma: Associations with crime and no child left behind programmes. *J Epidemiol Community Health*. 2011;65(10):859-865.
17. Alves GdC, Santos DN, Feitosa CA, Barreto ML. Community violence and childhood asthma prevalence in peripheral neighborhoods in Salvador, Bahia State, Brazil. *Cadernos de Saúde Pública*. 2012;28(1):86-94. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-311X2012000100009.
18. Vangeepuram N, Galvez MP, Teitelbaum SL, Brenner B, Wolff MS. The association between parental perception of neighborhood safety and asthma diagnosis in ethnic minority urban children. *J Urban Health*. 2012;89(5):758-768.
19. Hellyer J, Garrido EF, Petrenko CLM, Taussig HN. Are maternal and community risk factors associated with the presence of asthma among children placed in foster care? *Children and Youth Services Review*. 2013;35(1):128-132. doi: 10.1016/j.childyouth.2012.09.006.
20. Bellin M, Osteen P, Collins K, Butz A, Land C, Kub J. The influence of community violence and protective factors on asthma morbidity and healthcare utilization in high-risk children. *J Urban Health*. 2014;91(4):677-689. http://www.ncbi.nlm.nih.gov/pubmed/24889008. doi: 10.1007/s11524-014-9883-6.
21. Camacho-Rivera M, Kawachi I, Bennett GG, Subramanian SV. Perceptions of neighborhood safety and asthma among children and adolescents in Los Angeles: A multilevel analysis. *PloS one*. 2014;9(1):e87524. http://www.ncbi.nlm.nih.gov/pubmed/24466355. doi: 10.1371/journal.pone.0087524.
22. Koinis-Mitchell D, Kopel SJ, Salcedo L, McCue C, McQuaid EL. Asthma indicators and neighborhood and family stressors related to urban living in children. *Am J Health Behav*. 2014;38(1):22-30.
23. Kopel LS, Gaffin JM, Ozonoff A, et al. Perceived neighborhood safety and asthma morbidity in the school inner-city asthma study. *Pediatr Pulmonol*. 2015;50(1):17-24.
24. Ramratnam SK, Han Y-, Rosas-Salazar C, et al. Exposure to gun violence and asthma among children in Puerto Rico. *Respir Med*. 2015;109(8):975-981.
25. Beck AF, Huang B, Ryan PH, Sandel MT, Chen C, Kahn RS. Areas with high rates of police-reported violent crime have higher rates of childhood asthma morbidity. *The Journal of Pediatrics*. 2016;173:182.e1.

http://www.sciencedirect.com/science/article/pii/S0022347616001669. doi: 10.1016/j.jpeds.2016.02.018.
26. Eldeirawi K, Kunzweiler C, Rosenberg N, et al. Association of neighborhood crime with asthma and asthma morbidity among Mexican American children in Chicago, Illinois. *Ann Allergy Asthma Immunol*. 2016;117(5):507.e1.
27. Yakubovich AR, Cluver LD, Gie R. Socioeconomic factors associated with asthma prevalence and severity among children living in low-income South African communities. *South African Medical Journal*. 2016;106(4):407-412. doi: 10.7196/SAMJ.2016.v106i4.10168.
28. U.S. Department of Health and Human Services, National Heart, Lung, and Blood Institute. The national asthma education and prevention program. expert panel report 3 (EPR3): Guidelines for the diagnosis and management of asthma. . 2007.
29. Sampson RJ. How does community context matter? social mechanisms and the explanation of crime rates. In: *The explanation of crime.* Cambridge: Cambridge University Press; 2006:31-60. http://ebooks.cambridge.org/chapter.jsf?bid=CBO9780511489341&cid=CBO9780511489341A012. 10.1017/CBO9780511489341.003.
30. Wright RJ, Subramanian SV. Advancing a multilevel framework for epidemiologic research on asthma disparities. *CHEST Journal*. 2007;132(5 Suppl):769S. http://journal.publications.chestnet.org/content/132/5_suppl/757S.abstract. doi: 10.1378/chest.07-1904.
31. Goldman-Mellor S, Margerison-Zilko C, Allen K, Cerda M. Perceived and objectively-measured neighborhood violence and adolescent psychological distress. *J Urban Health*. 2016;93(5):758-769. https://search.proquest.com/docview/1826089970. doi: 10.1007/s11524-016-0079-0.
32. Guilbert TW, Garris C, Jhingran P, et al. Asthma that is not well-controlled is associated with increased healthcare utilization and decreased quality of life. *Journal of Asthma*. 2011;48(2):126-132. http://www.ncbi.nlm.nih.gov/pubmed/21128880. doi: 10.3109/02770903.2010.535879.
33. Storfjell J, Winslow B, Saunders J. Catalysts for change: Harnessing the power of nurses to build population health in the 21st century. *Robert Wood Johnson Foundation*. 2017.
34. World Health Organization. Framework and statement: Consultation on the drafts of the "health in all policies framework for country action.". *8th Global Conference in Health Promotion*. 2013.

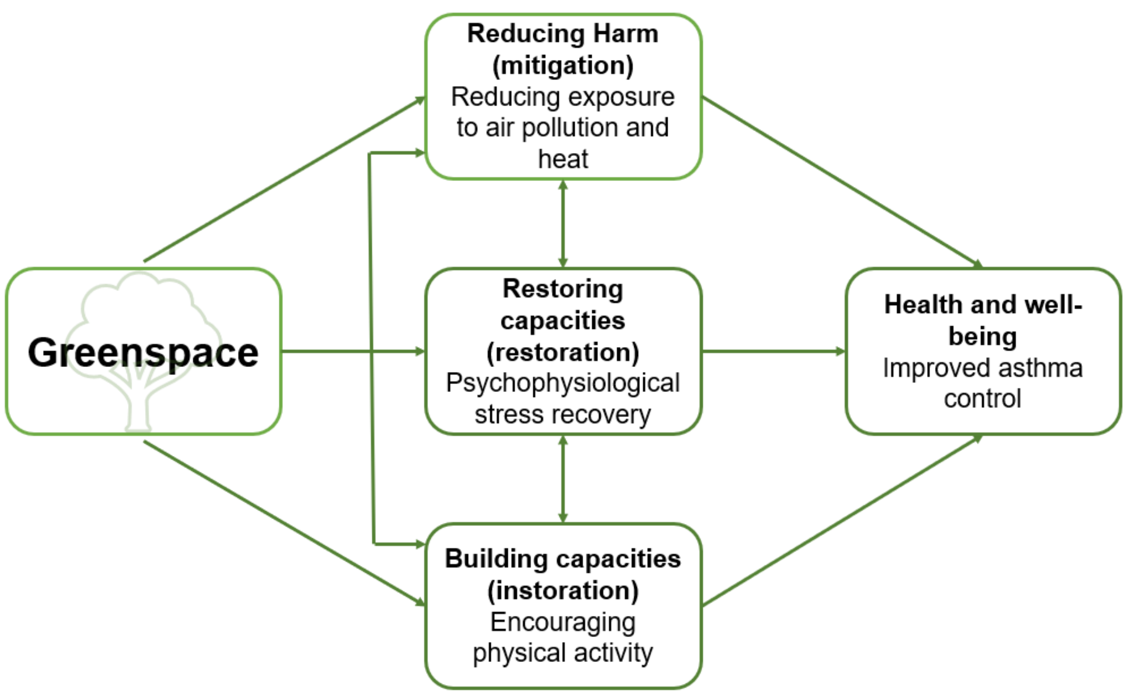
Appendix A. PubMed search strategy

(((((("Environment"[Mesh] OR "Social Environment"[Mesh]) OR "Residence Characteristics"[Mesh] OR (neighborhood* [tw] OR neighbourhood* [tw] OR residence [tw] OR residential [tw] OR residence characteristics [mh] OR community [tw])))) AND (((child [mh] OR infant [mh] OR adolescent [mh] OR infant* [tiab] OR toddler* [tiab] OR child* [tiab] OR youth [tiab] OR teen* [tiab] OR adolescen* [tiab])))) AND ((("Asthma"[Mesh] OR asthma [tw] OR wheez* OR "reactive airway disease" OR "reactive airway diseases" OR "reactive airway disorders" OR "allergic airway disease" OR "allergic airway diseases" OR bronchial hyperreactivity[mh] OR "respiratory hypersensitivity" OR ((bronchial* OR respiratory OR airway* OR lung) AND (hypersensitive* OR hyperreactive* OR allerg* OR insufficiency)))) AND ((("Safety"[Mesh]) OR (("Crime"[Mesh]) OR "Exposure to Violence"[Mesh])))
Filters: **Publication date from 2010/01/01**

CHAPTER 2: ADDENDUM: The relationship between neighborhood greenspace and children's asthma

Greenspace, defined as land with grass, trees, or other vegetation[17] in an urban environment, has been shown to decrease environmental heat and air-pollution.[22,67] Greenspace has also been associated with increased physical activity[27,68] and social connection[19] and reduced stress and obesity (Figure 1).[20,21] Given that heat, air pollution, obesity, stress, and sedentary lifestyles are all linked with poorer asthma control[69-71] some researchers have started to examine whether the availability of greenspace is associated with lower prevalence of asthma and better asthma control.[27,28,72] The purpose of this review is to summarize and critique current research linking neighborhood greenspace to children's asthma.

Figure 1. Conceptual Framework of domains through which greenspace improves asthma control.[44]



Three major databases (PubMed, CINAHL, and Psych Info) were searched for articles over the past ten years investigating the relationships between neighborhood greenspace and children's asthma. After applying the search criteria seven articles were included in this review. (See Table 1 for a detailed review of each individual study.)

One study, which examined the relationship between an indicator of greenspace (tree canopy) and asthma found that an increased percentage of tree canopy was significantly related to lower asthma prevalence in New York City (Relative Risk [RR] 0.71, [95% CI 0.64, 0.79]). However, no relationship was found between tree canopy and asthma ED rates (RR 0.89 [95% CI 0.75, 1.06]).[48] A similar study in Texas found no relationship between tree cover and incidence of asthma.[47] A third study found no association between asthma and green space, for participants not exposed to heavy traffic, when measuring percentage of "parkland" in community areas.[73] All three studies were limited by using tree canopy or percentage of "parkland," rather than a stronger measure of greenspace, such as the "normalized difference vegetation index" or NDVI. None of these studies were able to control for individual factors such as family socioeconomic status or exposure to potential asthma triggers within the home. This study will use NDVI to measure neighborhood greenspace and will control for individual factors that potentially confound the relationship between greenspace and asthma.

Greater NDVI scores within 100 meters of the child's home have been associated with lower asthma risk for preschool children (aOR 0.96 [95%CI 0.93, 0.99]).[27] Unfortunately, this study did not examine the association between greenspace and asthma control, an important indicator of asthma morbidity and mortality risk.[4] This study will examine associations between greenspace and indicators of the level of asthma control.

In contrast, two European studies in Spain and Lithuania found no relationship[72] or a negative relationship[29] between NDVI and asthma prevalence. Both of these studies were conducted in small cities where asthma rates were lower than those typical of urban cities in the US.[74] Thus, these findings may have limited generalizability to cities in the US reporting high asthma prevalence rates.

A recent study found parenting style to be a social factor that modified the relationship between greenspace (measured as NDVI) and asthma control. The interaction between harsh/inconsistent parenting and greenspace had a statistically significant correlation with asthma control (β=-0.15, p=0.02).[46] In other words, a decrease in harsh/inconsistent parenting strengthened the positive correlation between greenspace and asthma control. The study team found no association when examining associations between greenspace and asthma control alone. The study sample was low-risk in that the median family income was $100,000 and on average the children had relatively well-controlled asthma (mean asthma control score was 20.8 on a scale of 5-25, 25 being the optimum control). This study will expand on this idea by investigating a social variable, neighborhood safety, as a potential moderator in the relationship between greenspace and asthma control using a sample of predominantly African American children with poorly controlled asthma to determine if these relationships translate to children who are at higher risk for asthma related complications.

A recent study by Feng and Astell-Burt in Australia, tested greenspace as a potential protective factors against the associations among traffic exposure, lack of safety, and presence of asthma.[73] Greenspace was measured as the percentage of a defined community statistical area containing “parkland.” Traffic exposure was measured by asking parents to rate heavy traffic on their street using a likert scale. Parents were also asked to respond with whether they agreed or disagreed with the statement that they live in a safe neighborhood. The researchers found that children who were exposed to high traffic volumes and lived in areas with 0-20% greenspace had increased odds for asthma (OR 1.87; 95% CI [1.37, 2.55]). They also found that the association between heavy traffic and asthma was lower for those in areas with over 40% greenspace (OR for interaction= 0.32; 95% CI [0.12, 0.84]).[73] They did not find any association between asthma and neighborhood safety, nor was the relationship modified by testing an interaction between greenspace and safety. As was discussed previously, this research is limited in measurement of greenspace using percentage of "parkland." The measurement of safety could also be improved by asking additional questions to measure neighborhood safety or using an objective marker of neighborhood safety, such as neighborhood crime statistics.

To date, no study has investigated the association between greenspace and pediatric asthma control in African American children living in low-income communities. This study will address the limitations of previous studies by (a) employing a validated method (NDVI) for estimating neighborhood greenspace, (b) focusing on a sample of children at greatest risk for asthma-related morbidity and mortality (i.e., African American children living in poverty), (c) examining the relationship between the availability of neighborhood greenspace and asthma control based on parental report of symptoms, activity limitations and rescue inhaler use for the child in the preceding weeks, and (d) control for potential individual-level confounders.

Table 1. Greenspace and Children's Asthma

Author	Study	Methods	Greenspace Measurement	Asthma	Findings	Covariates
Lovasi[15] (2008) New York City, New York	Associations between street trees and asthma	Cross-sectional; children ages 4-5 and hospitalization for children <15 years old in 42 health service catchment areas.	Street tree counts provided by NYC Department of Parks and Rec. (# of trees on street segments divided by land area).	Asthma assessed by NYC Department of Health school screenings and hospital data.	An increase in tree density of 1 SD (343 trees/km^2) associated with a lower prevalence of asthma (RR 0.71, 95% CI 0.64-0.79) but not with hospitalizations for asthma (RR 0.89, 95% CI 0.75-1.06).	Proximity to pollution sources (toxic release inventory sites, stationary point sources and major truck routes), socio-demographics, and population density for each area calculated using the census.
Pilat[16] (2012) Texas, USA	Association of tree cover and vegetation with asthma	Cross-sectional; Children under 17 years old in 14 Metropolitan Statistical Areas (MSA) in TX	NDVI calculated for each MSA	"Has a physician/ medical care provider ever told you that your child has asthma?"	No relationship between overall vegetation and incidence of asthma (R^2=0.052, p=0.88).	Relative humidity, temperature, ozone, particulate matter, ethnicity within each MSA. (Could not control for exposure to secondhand smoke, pets, dust mites, or cockroaches).
Dadvand[12] (2014) Sabadell, Spain	Associations between green spaces, obesity, allergy and asthma	Cross-sectional; N=2,178 children aged 9-12 years old	NDVI buffers of 100m, 250m, 500m and 1,000m. Living within 300m of a forest or a park.	"Has your child ever had asthma? Has it been diagnosed by a physician?"	No relationship between 1 IQR increase in greenness and asthma or allergy. Living close to parks associated with a 60% higher relative prevalence of asthma (aOR1.6; 95% CI 1.09, 2.36).	School type (private or public), parental educational achievement, parental asthma, and exposure to secondhand smoke.
Andrusaityte[19] (2015) Kaunas, Lithuania	Associations between greenness and asthma	Nested Case-Control; N=1,489 children aged 4-6 years old	NDVI buffers 100m, 300m, 500m and distance to nearest city park	"Has your child ever had doctor-diagnosed asthma?"	IQR increase in NDVI-100m increased risk of asthma (OR 1.43 95% CI 1.10-1.85). Increase in NDVI not significantly associated with risk of asthma for all 3 buffers.	Home-address specific models of PM2.5 and ambient concentrations of NO2. Adjusted for mother's age, maternal education, parental asthma, maternal smoking during pregnancy, breastfeeding, and a cat in the home.
Sbihi[4] (2015) Vancouver, British Columbia	Associations between greenness and asthma incidence	Case-control; N=52,000 children age 0-10 years old	NDVI- 100m buffer around postal code ("reflects a city block)	Physician billing and hospital discharge records to identify those with asthma	Children 0-5 years had decreased risk of asthma per interquartile (0.11) NDVI increase (aOR=0.96, 95%CI 0.93-0.99). These associations were not observed for children 6-10 years old. No association between asthma and distance to nearest park.	First Nations status, sex, maternal parity, age, smoking during pregnancy, breastfeeding. Assigned neighborhood-level socioeconomic indicators from census data (household income and maternal education). Lack of individual level covariate data.
Chen[21] (2017) Chicago, Illinois, USA	Difficult family relationships, residential	Cross-sectional; N=150 children aged 9-17 years old	NDVI in 250m buffers around home address,	Parents completed the asthma control test (5 questions)	No relationship between greenspace and asthma control. Decrease in harsh/inconsistent parenting strengthens positive correlation between	Family income, season of visit, child demographics (age, sex, ethnicity [white or other]), child medical variables (asthma severity, atopic

	greenspace, and asthma		average across the year		greenspace and asthma control (β= -0.15, p=0.02)	status, inhaled corticosteroid use and B agonist use).
Feng[17] (2017) Australia	Is green space protective again traffic and lack of safety?	Cross-sectional: N=4,447 children age 6-7 years old. Multi-level analysis across statistical areas.	Percentage of "parkland" in each statistical area (administrative unit for communities) classified by Australian Bureau of Statistics	Yes, to all three; "Doctor" diagnosed asthma, asthma related medication use, and illness with wheezing lasting for at least 1 week within the 12 months prior	Children exposed to high traffic volumes and areas with 0 to 20% green space quantity, (OR for asthma=1.87 (95% CI 1.37 to 2.55). Association between heavy traffic and asthma significantly lower for those in areas with over 40% green space (OR for interaction=0.32, 95% CI 0.12 to 0.84). No association between asthma and green space for participants not exposed to heavy traffic, nor for the area safety variable.	Parent perception of traffic volume, parent response to statement, "This is a safe neighborhood." Participants' age and gender, maternal education, area socioeconomic disadvantage.

CHAPTER 3: MANUSCRIPT THREE: Investigating the relationships among neighborhood factors and asthma control in African American children: A study protocol

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Key words: childhood asthma, greenspace, neighborhood and built environments, neighborhood safety

Abstract

Over 2 million children in the US have uncontrolled asthma. African American children are disproportionately affected with a risk of dying from asthma that is 7.6 times higher than non-Hispanic White children. Racial disparities in childhood asthma are partially attributed to differential exposures to poverty; unsafe and stressful neighborhoods; and unhealthy physical environments. This paper describes the protocol for an ongoing NIH/NINR-funded descriptive, cross-sectional study investigating two neighborhood factors that may influence children's asthma. Building on an existing dataset, this study examines associations among neighborhood greenspace, neighborhood safety, and level of asthma control while controlling for indoor asthma triggers in an urban sample of predominantly low-income, African American children with persistent asthma. Two new variables are added to the dataset: availability of neighborhood greenspace and neighborhood violent crime rate. Greenspace is being accessed using geographic information systems (GIS) and measured using normalized difference vegetation index (NDVI). Neighborhood violent crime rate is calculated using geocoded, point locations for crimes downloaded from the city police department. It is hypothesized that parents living in unsafe neighborhoods are likely to keep their children indoors, thereby increasing their children's exposure to indoor asthma triggers and limiting the potential benefits of neighborhood greenspace. The biggest challenges thus far are related to limited variability in greenspace and violent crime rates. Progress to date and strategies to address these challenges are discussed. Results have the potential to inform interventions to improve asthmatic children's health and influence public health policy.

Introduction

Currently 6.1 million children in the United States have asthma,[1] with an estimated total cost of $81.9 billion annually in healthcare related expenditures and costs incurred by absenteeism and mortality.[2] Approximately 38% of these children have uncontrolled asthma defined as having 2 or more symptom days per week, more than 1 symptom night per month, activity limitation, and use of rescue medications more than 2 days per week.[3,4] Children with uncontrolled asthma use more healthcare resources and report lower quality of life when compared to children with controlled asthma.[5] The burden of asthma is not equally distributed across racial groups. According to a recent CDC report, 22.5% of African American children with asthma had an asthma-related emergency department visit in the past year compared to 12.2% of non-Hispanic white children with asthma.[1]

Racial disparities in asthma outcomes are likely attributable, in part, to differential exposures to neighborhood conditions since segregation and economic disadvantage influence neighborhood residence. These exposures include unhealthy physical environments, such as air pollution, poor quality of housing stock, presence of pests in the home, and exposure to secondhand smoke, and unhealthy social environments, due to violence and stress.[6] For example, children from low-income families are exposed to higher levels of traffic related air pollution; live in lower quality, more crowded, and noisier homes; and are exposed to more neighborhood violence compared to children from more affluent families.[7]

Neighborhood level factors including air pollution, poor housing stock, crime and violence, are shaped by both political and economic factors and can be difficult to change.[8] However, one potentially modifiable factor that may improve asthma control is the availability of greenspace, defined as land with grass, trees, or other vegetation.[9] Prior research indicates that neighborhood greenspace is associated with greater physical activity and social connection and with lower levels of perceived stress, environmental heat and air-pollution, variables that have been associated with asthma control in children.[10-12] Indeed, some studies have shown that increases in the "normalized difference vegetation index" or NDVI, a measure of the greenspace in a given geographical area, is associated with decreased asthma prevalence.[13] However, other studies have shown no effects or negative effects of greenspace on asthma prevalence and control.[14,15] One possible explanation for the mixed results is the failure to account for indicators of neighborhood safety, such as neighborhood violent crime rate and parent perceptions of neighborhood safety, which would affect parents' willingness to allow their children to use greenspace. Living in an unsafe neighborhood has been associated with greater stress and children spending less time outside resulting in increased exposure to indoor allergens and pollutants, including second hand smoke.[16,17] Research has demonstrated poor asthma control in areas with high violent crime compared to similar areas with low violent crime.[18] The purpose of this paper is to describe the protocol for an NIH/National Institute of Nursing Research-funded study examining the associations among greenspace, neighborhood safety and asthma control, while controlling for indoor asthma triggers, in children with asthma living in urban poverty.

Background

Low-income, African American children are disproportionately affected by asthma. Asthma is the most common cause of all Pediatric Emergency Department (ED) visits.[19] Repeated ED visits are an index for poorly controlled asthma as children with frequent ED visits are at the greatest risk for life-threatening asthma, decreased quality of life, and increased school absences.[3] Uncontrolled asthma also leads to inflammation and airway remodeling that may contribute to long-term loss of lung function and impairment.[20] Low-income, African American children have 4.1 times more ED visits and a death rate that is 7.6 times higher than that of non-Hispanic White children.[21] There is strong evidence that environmental exposures are important contributors to high rates of asthma-related morbidities.[22] Environmental factors such as chronic exposures to indoor allergens, secondhand smoke, air pollution, violence, and toxic stress; sedentary lifestyles; and obesity are differentially distributed according to economic disadvantage.[23] Limited access to guideline-based preventative care in low-income underserved communities also contributes to higher rates of uncontrolled asthma.[24] The National Asthma Education and Prevention Program (NAEPP) Expert Panel Report 3, published by the National Heart, Lung, and Blood Institute (NHLBI), identified a history of "low socioeconomic status or inner-city residence" as a key risk factor for asthma related mortality.[3] Baltimore City has the highest rate of pediatric asthma hospitalizations in Maryland and one of the highest in the nation.[25] Identifying modifiable factors that can lead to improved asthma control among African American children growing up in urban poverty has been named a research priority by the Environmental Protection Agency(EPA), Healthy People 2020, and supports the National Institute of Nursing Research's goal to understand environmental determinants of health in those with chronic disease.[26-28]

Availability of greenspace may be a protective factor for children with asthma. Greenspace in an urban environment, has been shown to decrease environmental heat and air-pollution.[29] Greenspace has also been associated with increased physical activity and social connection and reduced stress and obesity.[12] Given that heat, air pollution, obesity, stress, and sedentary lifestyles are all linked with poorer asthma control some researchers have started to examine whether the availability of greenspace is associated with lower prevalence of asthma and better asthma control.[30] See Chapter 1 Figure 1 for the conceptual framework of these relationships.

Several studies have examined the relationship between greenspace and asthma prevalence rates. Although some have found significant relationships suggesting greenspace may have positive effects on asthma rates,[13,31] the few that looked at asthma control did not find significant health effects.[31,32] Although asthma rates are important health indicators, rates of asthma control are stronger indicators of morbidity and mortality risk.[3] This study examines associations between greenspace and indicators of the level of asthma control in a low-income, high risk pediatric population.

It is important to note that not all studies that have examined the relationship between greenspace and asthma prevalence have uncovered a significant health effect.[15,33] However, some of these studies were conducted in small cities where asthma rates were low, which may have contributed to floor effects.[30] Some studies were limited by using tree canopy, rather than a stronger measure of greenspace, such as "normalized difference vegetation index" or NDVI.[31] NDVI is a validated, practical measure of greenspace.[34] In all of the studies thus far, none controlled for the effects of neighborhood safety. This study uses NDVI to measure neighborhood greenspace based in an urban city with higher than average rates of both pediatric asthma and neighborhood violence.

To date, no study has investigated the association between greenspace and pediatric asthma control in low-income, hyper segregated, urban communities. This study will address the limitations of previous studies by (a) employing a validated method (NDVI) for estimating neighborhood greenspace, (b) focusing on a sample of children at greatest risk for asthma-related morbidity and mortality (i.e., African American children living in urban poverty), and (c) examining the relationship between the availability of neighborhood greenspace and asthma control based on the parent report of symptoms, activity limitations and rescue inhaler use for the child in the preceding weeks.

Neighborhood safety may be a potentially important modifying factor that prevents the use of greenspace. Markers of neighborhood safety such as violent crime, which tend to be higher in low-income, hyper segregated neighborhoods,[35] may limit the benefits of greenspace on children's asthma control as parents may be less likely to allow their children outdoors. Neighborhood safety can be captured objectively using neighborhood violent crime statistics and subjectively using parents' perceptions of neighborhood safety. Although it is likely these two estimates of neighborhood safety are related because parents acquire perceptions of neighborhood safety, at least in part, based on the amount of violent crime occurring in their neighborhood, parent perceptions of neighborhood safety may be a stronger predictor of child health outcomes. For example, neighborhood crime statistics capture averages by designated community statistical areas (CSAs). However, parents may base their assessments of neighborhood safety on a different concept of where their neighborhood falls, a single incident that occurred in an otherwise low-risk neighborhood, or a personal encounter with violence, that may not be fully reflected in CSA crime statistics.

Parents who perceive their neighborhoods as unsafe are likely to keep their children indoors, which would reduce risk of harm but, also increase their exposure to indoor asthma triggers including; cockroaches, mice, rats, and secondhand smoke, and limit their physical activity.[16,30,36] Research has demonstrated a link between parent perception of the neighborhood as unsafe and poor asthma control.[37,38] Parent perception of neighborhood safety may also affect the parent's level of stress leading to unhealthy coping behaviors such as smoking, which is more common in low-income, urban communities.[39] Secondhand smoke exposure is also a known trigger for children with asthma.[16,40]

Unsafe neighborhoods can also increase child stress thereby affecting the inflammatory response.[41] For example, asthmatic children exposed to acute stressors have increased airway inflammation; an effect found to be greatest among low-income children.[42] Over time chronic stress exposure can modify the hypothalamic-pituitary-adrenal axis which alters the way individuals physiologically respond to asthma triggers, prompting more frequent exacerbations.[43] In two studies utilizing violent crime statistics, areas with higher violent crime rates had higher numbers of asthma ED visits in Cincinnati[18] and higher asthma prevalence in Chicago[44] compared to areas in the same cities with lower violent crime rates. This body of research, predominantly done in low-income communities, demonstrates a link between safety and asthma control but fails to control for exposure to indoor triggers.

This study controls for indoor triggers and examines two different indicators of neighborhood safety, neighborhood violent crime statistics and parent perception of neighborhood safety, to determine if one measure is a stronger predictor of asthma control. If parent perception of neighborhood safety is a stronger predictor of asthma control than neighborhood crime statistics (Aim 2; H2C), it may suggest that parent stress and perceptions play a more important role in understanding how neighborhood factors affect children's asthma control. Looking at these indicators of neighborhood safety separately will inform future research into differing mechanisms of the association between neighborhood safety and asthma control. This study is also the first to analyze neighborhood safety as a potential modifier in the relationship between greenspace and asthma control. These relationships are depicted in Chapter 1 Figure 1. Research accounting for the larger context of neighborhood environment including neighborhood safety will inform more effective implementation of greenspace initiatives in urban areas with high rates of poverty, violence, and asthma like Baltimore.

Research Design and Methods

Study Design: This study uses a cross-sectional design to analyze the role of neighborhood safety in understanding the extent to which the availability of greenspace may benefit children with asthma living in urban poverty.

Building on an existing randomized controlled trial of parents of children with asthma,[45] this study uses multiple measures and informants to capture study variables including geocoding, neighborhood crime statistics, parent reports, and physiologic measures. Data analysis will control for indoor asthma triggers as well as season of baseline data collection. In a sample of 222 predominantly African American, low-income children living with asthma in Baltimore City the specific aims of this study are:

Specific aim 1. Examine the association between neighborhood greenspace and level of asthma control.

Hypothesis 1: Higher index of neighborhood greenspace (measured as NDVI) will be associated with better asthma control.

Specific aim 2. Examine the association among neighborhood safety, measured as violent crime victimization rate and parent perception of neighborhood safety, and level of asthma control. Hypothesis 2A: Higher rates of violent crime victimization will be related to poor asthma control; Hypothesis 2B: Parent perception of an unsafe neighborhood will be associated with poor asthma control. Hypothesis 2C: Parent perception of neighborhood safety is more strongly associated with level of asthma control than violent crime victimization rate.

Specific aim 3. Explore neighborhood safety (violent crime victimization rate and parent perception of neighborhood safety) as a potential moderator in the association between neighborhood greenspace and level of asthma control.

Hypothesis 3: Neighborhood safety will moderate the relationship between greenspace and level of asthma control.

Sampling and Recruitment. The data set for the current study includes baseline data collected from 222 parent/child dyads enrolled in a larger study testing the efficacy of a behavioral intervention for improving pediatric asthma control.[45] These parent/child dyads were recruited August 2013 through February 2016 after presenting to the Johns Hopkins Hospital Pediatric Emergency Department due to asthma exacerbation. **Child inclusion criteria** were (a) physician diagnosed asthma, (b) ≥2 ED visits or 1 hospitalization for asthma within the past year, (c) mild to severe persistent asthma based on NHLBI guidelines criteria,[3] (d) 3-12 years old, (e) resides in Baltimore City, (f) they or a sibling not currently participating in an asthma study. **Child exclusion criteria** were (a) inability to speak and understand English, (b) no access to a working phone for follow-up surveys, (c) co-morbid respiratory condition and (d) situation where consent cannot be obtained from legal guardian. **Parent/legal guardian inclusion criteria** were (a) parent/legal guardian of child with asthma age 3-12 years attending the Johns Hopkins Hospital Pediatric Emergency Departments for acute asthma treatment and the child meets inclusion criteria above, (b) reside in Baltimore City, (c) ability to read at basic or 4th grade level. Reading level tested during consent process by asking the consentee to read a part of the consent. **Parent/legal guardian exclusion criteria** were (a) inability to speak and understand English, (b) no access to a working phone for follow-up surveys. If criteria were met, parents were consented, and children age 7-12 years signed a written assent form. Parents were remunerated $30 for baseline survey participation. The parent study and the current study were both approved by the Johns Hopkins Medicine Institutional Review Board.

Neighborhood Level Data. Conceptually, the neighborhood is defined as an overlapping area of ecological units varying in size (e.g. a block is smaller than a census tract) and including an inconsistently interacting group of people and institutions.[46] For this research, neighborhood will be operationalized as community statistical area (CSA). The Baltimore City CSAs were originally defined by the Baltimore Data Collaborative with the Baltimore City Department of Planning to provide a consistent representation of the conditions within particular neighborhoods.[47] The CSAs align with census tracts and reflect the City planner's understanding of residents' perception of the boundaries of the community.[47] There are 55 CSAs in Baltimore City. Other studies have used census tracts or zip codes to define neighborhood boundaries, but research shows the results are robust to different methods of operationalizing neighborhood boundaries.[46] Participant addresses were geocoded using ArcGIS software.[48] Please refer to Figure 2 for the geocoded map containing Baltimore City CSAs, participant locations, and asthma control for each participant. Once geocoded, using a spatial join in ArcGIS the addresses were assigned to their CSAs for analysis.

Variables and Measures. Table 1 presents the study variables, measures, informant, evidence of reliability/validity, and whether the data was collected for the parent study ("Existing Data") or obtained by the applicant for this protocol ("New Data").

Asthma Control (Existing Data). Consistent with national guidelines, asthma control was calculated based on caregiver report of (1) the number of symptom days over the past 14 days, (2) the number of symptom nights over the past 30 nights, (3) activity limitation over the past week, and (4) short-acting β_2-agonist use over the past two weeks.[3] These variables were included in an algorithm to categorize each child by whether they their asthma was poorly controlled (yes or no).

Asthma Triggers and Allergen Sensitization (Existing Data). At baseline, 5ml of the child's blood was drawn to measure IgE antibodies to ten common environmental allergens: mouse, cockroach, cat, dog, timothy grass, Alternaria and aspergillus molds, oak tree, common ragweed, and house dust mite. Saliva was also collected (1mL) to measure salivary cotinine concentration, a biomarker for the child's level of nicotine exposure in the past 24 hours. Parents were asked if they had seen roaches, rats, or mice in their home in the past three months. These data were included as potential covariates.

Family Background Information (Existing Data). During baseline enrollment parents filled out the baseline questionnaire to collect data on demographics, asthma medication use, daily stress, home asthma trigger exposures and perceived neighborhood safety. During this time parents were also asked their home address and amount of time they resided at their home address.

Greenspace (New Data). Greenspace was calculated by determining the normalized difference vegetation index (NDVI). This index, ranging from -1 to 1 with higher numbers indicating more greenness, has been shown to accurately measure the proportion of ground covered by green vegetation.[49] NDVI was derived from the Landsat Enhanced Thematic Mapper Plus (ETM+) data at 30m by 30m resolution.[50] The ETM + Landsat data was downloaded for the Baltimore City region for 2013, the first year of study enrollment, from the United States Geological Survey (https://lta.cr.usgs.gov/LETMP). NDVI was calculated by pixel and averaged for each Community Statistical Area.

Neighborhood Violent Crime Victimization Rate (New Data). For 2013, the first year of study enrollment, geocoded point locations for victim-based crimes supplied by the Baltimore City Police Department were downloaded from Open Baltimore (https://data.baltimorecity.gov/). These data were downloaded for the full years of 2013, 2014 and 2015 and were stratified to include violent crimes, per the Federal Bureau of Investigation's Uniform Crime Reporting Program,[51] comprising homicide/manslaughter, rape, aggravated assault, and robbery. Violent crime victimization rate was calculated by year by dividing the number of violent crime victimizations recorded by the Baltimore City Police Department by the population in each CSA.

Power Analysis. The power analysis, conducted prior to addition of GIS data, is based on preliminary analyses of the distribution of level of asthma control in the data set. Assuming, that the variables of NDVI and violent crime rate will be skewed,[15,18] these variables will be dichotomized to low versus high. Of the 222 children, 63.5% have poorly controlled asthma and 36.5% do not have poorly controlled asthma. Using this rate for the outcome and varying the intra-class correlation associated with CSA and percent with high greenspace or rate of violence index (predictor variable) determined the odds ratio detectable with statistical power of .80, alpha level of .05, and n=222. Table 2 summarizes the results for predictors of asthma control based on the distribution. For example, with statistical power at 0.80, alpha at 0.05 and n=222 if greenspace is distributed as 50 percent high greenspace and 50 percent low greenspace, and the Intra-class Correlation Coefficient is 0.10, the study is powered to detect an Odds Ratio of 2.17. The predictor distribution can also be used to determine detectable odds ratios depending on the distribution of violent crime rate (low versus high). For the continuous predictor of caregiver perception of safety, significant odds ratios are detectable at 1.55, 1.52, and 1.49 if the ICC is 0.20, 0.15, and 0.10, respectively assuming power of .80, alpha of .05 and sample size of 222.

Procedures. Building upon baseline data, home address was used to geocode the child's place of residence using the geospatial referencing software, ArcGIS version 10.5.1.[48] NDVI data was added for 2013 using satellite imagery from April 2013. This particular image was chosen because it was during a green month with limited cloud cover over Baltimore City. Regardless of date of enrollment all participants have corresponding NDVI values calculated from the April 2013 data. Previous research demonstrates that measurement of NDVI is stable over several years.[50] Neighborhood violent crime victimization rate was calculated per year for 2013, 2014, and 2015 and assigned to each child depending upon their year of enrollment into the study. If the child was enrolled August 2013 through the end of June 2014, they were assigned the violent crime victimization rate from 2013; those enrolled from July 2014 through the end of June 2015 were assigned the violent crime victimization rate from 2014; and those enrolled from July 2015 through February 2016 were assigned the violent crime victimization rate from 2015. Length of time at their residence will be included as a potential covariate during data analysis.

Data Analysis Plan. Preliminary analysis will be completed for all study variables to determine if the distribution of the variables meet the assumptions for inferential statistical tests. Variables will be examined for normality and examined with means and standard deviations or medians and interquartile ranges accordingly. If the variables are skewed, statistical approaches that fit the variable natural distribution (i.e., negative binomial, gamma) will be used if possible. The pattern of missing data will be explored, and t-tests and chi-squared tests used to determine if there are differences between those with and without missing data. The significance level will be set at 0.05. All tests will be two-tailed.

Aim 1. Examine the association between neighborhood greenspace and level of asthma control. H1: Higher index of neighborhood greenspace (measured as NDVI) will be associated with better asthma control.

The primary outcome is level of asthma control defined as either poorly controlled or not poorly controlled. The hypothesis will be tested using a multi-level logistic regression model with the child specific variables in the first level and neighborhood CSA in the second level. The purpose of the analysis is to determine if amount of CSA greenspace is associated with asthma control across CSAs controlling for season of enrollment, race/ethnicity, age, sex, indoor asthma triggers, parental education, parent marital status and family income. These covariates will be entered into the model first, followed by greenspace, the independent variable of interest. Individuals will be nested within CSA which will provide robust standard errors. A significant positive coefficient for greenspace will indicate support for the hypothesis.

Aim 2. Examine the associations among neighborhood safety, measured as violent crime victimization rate and parent perception of neighborhood safety, and level of asthma control. H2A: Higher rates of violent crime victimization will be related to poor asthma control; H2B: Parent perception of an unsafe neighborhood will be associated with poor asthma control. H2C: Parent perception of neighborhood safety will be more strongly associated with level of asthma control than violent crime victimization rate.

The hypotheses will be tested similar to the method from aim 1 with asthma control (i.e. poorly controlled [yes/no]) as the dichotomous outcome. For hypotheses 2A and 2B violent crime victimization rate and parent perception of safety will be examined in separate models including all covariates (season of enrollment, race/ethnicity, age, sex, indoor asthma triggers, parental education, parent marital status and family income). To test hypothesis 2C violent crime victimization rate and parent perception of neighborhood safety will be entered into the model simultaneously to determine the relative contribution of the two variables to asthma control.

Aim 3. Explore neighborhood safety (violent crime victimization rate and parent perception of neighborhood safety) as a potential moderator in the association between neighborhood greenspace and level of asthma control. H3: Neighborhood safety will moderate the relationship between greenspace and level of asthma control.

Moderation is considered to occur when the presence of a third variable affects the direction and/or strength of the association between an independent variable and a dependent variable [52]. Interaction terms will be created for (1) greenspace with violent crime victimization rate and (2) greenspace with parent perception of neighborhood safety. Interaction terms will be added to the models described in aim 2 along with greenspace to test hypothesized moderation. Separate analyses will be conducted for violent crime victimization rate and parent perception of neighborhood safety. These moderator analyses are likely to be under powered, therefore, the effect size associated with the interaction will be examined in addition to statistical significance.

Discussion

There are two major innovative aspects of this study. First, multiple methods and informants (geocoding, neighborhood crime statistics, parent reports, and child physiologic measures) will be examined to understand how neighborhood factors are linked to asthma control for predominantly African American, low-income children. Second, the study will be the first to include multiple measures of neighborhood safety, neighborhood violent crime victimization rate and parent perception of neighborhood safety, to better understand its role in modifying the potential benefits of neighborhood greenspace.

One of the benefits of building on an existing database is the ability to maximize the resources that have already been invested to recruit and collect data from a highly vulnerable population of parents and children, without any additional burden to participants.[53] For example, in this study I am able to use the data on asthma control and parent perception of neighborhood safety that was obtained for the original study and add new data on greenspace and neighborhood violent crime rate using publicly available data.

At present, the additional neighborhood data has been added to the existing data set as the final step before data analysis can begin in summer 2018. The challenges of building on existing data are that the methodological approach must include consideration of the available power, data quality and adequacy of the existing data set to answer the research question.[53] The power analysis demonstrated that the study was appropriately powered, given previous research in the area and the variability of asthma control by CSA from the parent study data. We knew that the research question would benefit from maximizing variability in the neighborhood residences of the study sample. But as we begin data analysis, we are finding limited variability. Perhaps this is due to economic segregation that clusters in poverty specific neighborhoods, a problem that has grown tremendously in this country over the last several decades especially among families with children.[54] Another potential explanation could be that families living in particular catchment areas are likely to seek care at Johns Hopkins Hospital.

Study participants live across 37 of the 55 CSAs in Baltimore and 77% live in areas with higher poverty compared to the average in Baltimore City.[47] Research has found that those living in poverty have lower greenspace coverage than those who do not live in poverty.[55] Therefore, when average NDVI was calculated for each CSA, the range [0.02, 0.14; standard deviation (SD) = 0.035] did not contain enough variability across CSAs to analyze the data measured at this level. To maximize greenspace variability, we revised the definition to include NDVI in circular areas, known as "buffers" in ArcGIS, with radii of 100m, 250m, 500m, and 1,000m, around each individual's home. Measurement of buffers, a proximal measure of greenspace, has more variability than the administrative unit of CSAs and its validity has been supported by others.[13,32] For example, the NDVI range for the 100m buffer was [0.00, 0.20; SD=0.039] with a slightly higher SD than when measured by CSA. Variability of the violent crime rate across CSAs was also limited (range [7.5, 32.7]; SD=6.66). To increase variability, violent crime rate was re-analyzed by census tract (range [4.9, 39.6]; SD=9.17), a smaller administrative unit that allowed for more variability across neighborhoods. This adjustment is congruent with current literature.[18,56] Although there are challenges related to the use of existing data, thus far, the benefits have outweighed the drawbacks.

Limitations. The study limitations are based on study design, measurement of the independent variables, and the study sample. Because this study is building on a parent study there are certain variables that will not be explored in full. For example, we were not able to ask children how much time they spent outside exposed to greenspace. We can only infer that those living in areas with higher greenspace have higher exposure. We have the advantage, however, of being able to add two variables to the data set in order to investigate the phenomena of interest. In addition, the sample size cannot be increased thus the study is not adequately powered to test moderation. Due to this limitation, analysis of aim three will consider effect size, as well as statistical significance, to inform future research.

As with all choices for measurement there are limitations and advantages. Violent crime victimization point pattern data only contain information on violent crimes that were reported to police officers, potentially leading to underestimation of the violent crime rate. If anything, this underestimation would bias results toward the null. For the purposes of obtaining objective, publicly available data, crime data from police departments is the best option. One limitation of using NDVI to measure greenspace is that this method does not provide information regarding the quality of the greenspace. Due to study design, we were not able to ask parents about the quality of greenspace surrounding their homes. Overall, measuring greenspace using NDVI was efficient and consistent with previous research. In future studies we plan to investigate greenspace quality and exposure.

All of the children in the study sample have persistent asthma, potentially leading to ceiling effects in the outcome variable, level of asthma control. This decreased variability might bias results towards the null. That being said, these children represent those at highest risk for asthma related morbidity and mortality in that they are predominantly low-income and African American. Therefore, the results of research seeking to improve asthma control for this population have the potential to make a strong impact. We will be mindful not to generalize our results beyond the scope of this research.

Conclusions about causal relationships among the study variables cannot be inferred based on the cross-sectional nature of the study design. However, we anticipate that the results can be used to guide the development of experimental designs to rigorously test the effect of increasing children's neighborhood greenspace exposure on asthma control, particularly among children growing up in unsafe neighborhoods.

Conclusion

This study focuses on vulnerable children at high-risk for asthma related morbidity and mortality. Using multiple methods and informants to investigate modifiable neighborhood factors we will examine how these factors may influence asthma control. The long-term goal of this research is to inform policies and practices for improving health outcomes for children with asthma living in urban poverty by understanding the role greenspace and neighborhood safety might play in asthma control.

References

1. Zahran H, Bailey C, Damon S, Garbe P, Breysse P. Vital signs: Asthma in children - united states, 2001-2016. *US Department of Health and Human Services/Centers for Disease Control and Prevention*. 2018:149-155.
2. Nurmagambetov T, Kuwahara R, Garbe P. The economic burden of asthma in the united states, 2008–2013. *Annals of the American Thoracic Society*. 2018;15(3):348-356. https://search.proquest.com/docview/2021667795. doi: 10.1513/AnnalsATS.201703-259OC.
3. U.S. Department of Health and Human Services, National Heart, Lung, and Blood Institute. The national asthma education and prevention program. expert panel report 3 (EPR3): Guidelines for the diagnosis and management of asthma. . 2007.
4. U.S. Department of Health and Human Services, Center for Disease Control and Prevention, National Center for Environmental Health. Behavioral risk factors surveillance systems- child and adults asthma callback survey data, 2006-2010. . 2015.
5. Braido F. Failure in asthma control: Reasons and consequences. *Scientifica*. 2013;2013:1-15. https://doaj.org/article/dc21d4685d7145d79acf9e1e918f143c. doi: 10.1155/2013/549252.
6. DePriest K, Butz A. Neighborhood-level factors related to asthma in children living in urban areas. *J SCH NURS (SAGE)*. 2017;33(1):8-17.
7. Evans GW, Kim P. Childhood poverty, chronic stress, Self-Regulation, and coping. *Child Development Perspectives*. 2013;7(1):43-48. https://onlinelibrary.wiley.com/doi/abs/10.1111/cdep.12013. doi: 10.1111/cdep.12013.
8. Gomez MB. Policing, community fragmentation, and public health: Observations from Baltimore. *Journal of urban health : bulletin of the New York Academy of Medicine*. 2016;93 Suppl 1:154. http://www.ncbi.nlm.nih.gov/pubmed/26753881. doi: 10.1007/s11524-015-0022-9.
9. US Environmental Protection Agency. What is open space/green space. https://www3.epa.gov/region1/eco/uep/openspace.html. Updated 2016.
10. Tosca MA, Ruffoni S, Canonica GW, Ciprandi G. Asthma exacerbation in children: Relationship among pollens, weather, and air pollution. *Allergologia et Immunopathologia*. 2014;42(4):362-368. http://www.ncbi.nlm.nih.gov/pubmed/23755880. doi: 10.1016/j.aller.2013.02.006.
11. Wanrooij VHM, Willeboordse M, Dompeling E, van de Kant, K D G. Exercise training in children with asthma: A systematic review. *British Journal of Sports Medicine*. 2014;48(13):1024-1031. http://www.narcis.nl/publication/RecordID/oai:cris.maastrichtuniversity.nl:publications%2F74ab397b-16b4-472d-92a9-61db71d86e7f. doi: 10.1136/bjsports-2012-091347.
12. Hartig T, Mitchell R, Vries d, S, Frumkin H. Nature and health. *Annual Review of Public Health*. 2014;35(1):207-228. http://www.narcis.nl/publication/RecordID/oai:library.wur.nl:wurpubs%2F448230. doi: 10.1146/annurev-publhealth-032013-182443.

13. Sbihi H, Tamburic L, Koehoorn M, Brauer M. Greenness and incident childhood asthma: A 10-year follow-up in a population-based birth cohort. *Am J Respir Crit Care Med*. 2015;192(9):1131-1133.
14. Fuertes E, Markevych I, Bowatte G, et al. Residential greenness is differentially associated with childhood allergic rhinitis and aeroallergen sensitization in seven birth cohorts. *Allergy Eur J Allergy Clin Immunol*. 2016.
15. Dadvand P, Villanueva CM, Font-Ribera L, et al. Risks and benefits of green spaces for children: A cross-sectional study of associations with sedentary behavior, obesity, asthma, and allergy. *Environ Health Perspect*. 2014;122(12):1329-1335.
16. Kanchongkittiphon W, Mendell MJ, Gaffin JM, Wang G, Phipatanakul W. Indoor environmental exposures and exacerbation of asthma: An update to the 2000 review by the institute of medicine. . 2015;123(1):6. http://nrs.harvard.edu/urn-3:HUL.InstRepos:13890681.
17. Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: Evidence from a national longitudinal study. *American Journal of Epidemiology*. 2013:kws353.
18. Beck AF, Huang B, Ryan PH, Sandel MT, Chen C, Kahn RS. Areas with high rates of police-reported violent crime have higher rates of childhood asthma morbidity. *The Journal of Pediatrics*. 2016;173:182.e1. http://www.sciencedirect.com/science/article/pii/S0022347616001669. doi: 10.1016/j.jpeds.2016.02.018.
19. Akinbami LJ, Moorman JE, Bailey C, et al. Trends in asthma prevalence, health care use, and mortality in the United States, 2001-2010. *NCHS data brief*. 2012(94):1-7. http://www.ncbi.nlm.nih.gov/pubmed/22617340.
20. Grainge CL, Lau LCK, Ward JA, et al. Effect of bronchoconstriction on airway remodeling in asthma. *The New England Journal of Medicine*. 2011;364(21):2006-2015. http://www.ncbi.nlm.nih.gov/pubmed/21612469. doi: 10.1056/NEJMoa1014350.
21. Akinbami LJ, Moorman JE, Garbe PL, Sondik EJ. Status of childhood asthma in the United States, 1980-2007. *Pediatrics*. 2009;123(Supplement):S145. http://pediatrics.aappublications.org/cgi/content/abstract/123/Supplement_3/S131. doi: 10.1542/peds.2008-2233C.
22. Meyers, D. A. Bleecker, E.R., Holloway JW, Holgate ST. The genetics of asthma: Towards a personalized approach to diagnosis and treatment. *The Lancet. Respiratory Medicine*. 2014;2(5):405.
23. Forno E, Celedón J. Asthma and ethnic minorities: Socioeconomic status and beyond. *Current Opinion in Allergy and Clinical Immunology*. 2009;9(2):154-160. http://www.ncbi.nlm.nih.gov/pubmed/19326508. doi: 10.1097/ACI.0b013e3283292207.
24. Butz AM, Kub J, Bellin MH, Frick KD. Challenges in providing preventive care to inner-city children with asthma. *The Nursing clinics of North America*. 2013;48(2):241-257. http://www.ncbi.nlm.nih.gov/pubmed/23659811. doi: 10.1016/j.cnur.2013.01.008.
25. Kelly L, Burkhart K. Asthma and air pollution in Baltimore city. *Environmental Integrity Project*. 2017.

26. United States Department of Health and Human Services. The NIH almanac: National institute of nursing research. . Updated 2016.
27. United States Environmental Protection Agency. Asthma research. . Updated 2016.
28. United States Department of Health and Human Services. Healthy people 2020: Respiratory diseases. . Updated 2016.
29. Nowak DJ, Crane DE, Stevens JC. Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry & Urban Greening*. 2006;4(3):115-123. http://www.sciencedirect.com/science/article/pii/S1618866706000173. doi: 10.1016/j.ufug.2006.01.007.
30. Quinto KB, Zuraw BL, Poon KT, Chen W, Schatz M, Christiansen SC. The association of obesity and asthma severity and control in children. *The Journal of Allergy and Clinical Immunology*. 2011;128(5):964-969. http://www.sciencedirect.com/science/article/pii/S0091674911010037. doi: 10.1016/j.jaci.2011.06.031.
31. Lovasi GS, Quinn JW, Neckerman KM, Perzanowski MS, Rundle A. Children living in areas with more street trees have lower prevalence of asthma. *J Epidemiol Community Health*. 2008;62(7):647-649.
32. Chen E, Miller GE, Shalowitz MU, et al. Difficult family relationships, residential greenspace, and childhood asthma. *Pediatrics*. 2017;139(4):1-10.
33. Pilat MA, McFarland A, Snelgrove A, Collins K, Waliczek TM, Zajicek J. The effect of tree cover and vegetation on incidence of childhood asthma in metropolitan statistical areas of Texas
. *Horticultural Technology*. 2012;5(22):631-637.
34. Rhew IC, Vander Stoep A, Kearney A, Smith NL, Dunbar MD. Validation of the normalized difference vegetation index as a measure of neighborhood greenness. *Annals of Epidemiology*. 2011;21(12):946-952. https://www.sciencedirect.com/science/article/pii/S104727971100250X. doi: 10.1016/j.annepidem.2011.09.001.
35. Williams DR, Sternthal M, Wright RJ. Social determinants: Taking the social context of asthma seriously. *Pediatrics*. 2009;123(Supplement):S174. http://pediatrics.aappublications.org/cgi/content/abstract/123/Supplement_3/S174. doi: 10.1542/peds.2008-2233H.
36. Carver A, Timperio A, Crawford D. Playing it safe: The influence of neighbourhood safety on children's physical activity—A review. *Health and Place*. 2008;14(2):217-227. http://www.sciencedirect.com/science/article/pii/S1353829207000536. doi: 10.1016/j.healthplace.2007.06.004.
37. Kopel LS, Gaffin JM, Ozonoff A, et al. Perceived neighborhood safety and asthma morbidity in the school inner-city asthma study. *Pediatric Pulmonology*. 2015;50(1):17-24. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4096619/. doi: 10.1002/ppul.22986.
38. Bellin M, Osteen P, Collins K, Butz A, Land C, Kub J. The influence of community violence and protective factors on asthma morbidity and healthcare utilization in high-risk children. *J Urban Health*. 2014;91(4):677-689. http://www.ncbi.nlm.nih.gov/pubmed/24889008. doi: 10.1007/s11524-014-9883-6.
39. Wright RJ, Subramanian SV. Advancing a multilevel framework for epidemiologic research on asthma disparities. *CHEST Journal*. 2007;132(5 Suppl):769S.

http://journal.publications.chestnet.org/content/132/5_suppl/757S.abstract. doi: 10.1378/chest.07-1904.
40. Lang JE, Dozor AJ, Holbrook JT, et al. Biologic mechanisms of environmental tobacco smoke in children with poorly controlled asthma: Results from a multicenter clinical trial. *Journal of Allergy and Clinical Immunology: In Practice*. 2013;1(2):172-180.
41. Janusek LW, Tell D, Fishe K, Gaylord-Harden N, Mathews H. Influence of childhood adversity and neighborhood violence on inflammatory risk in young urban African American men. *Brain, Behavior, and Immunity*. 2012;26:S34. doi: 10.1016/j.bbi.2012.07.144.
42. Marin TJ, Chen E, Munch JA, Miller GE. Double-exposure to acute stress and chronic family stress is associated with immune changes in children with asthma. *Psychosomatic Medicine*. 2009;71(4):378-384. http://www.ncbi.nlm.nih.gov/pubmed/19196805. doi: 10.1097/PSY.0b013e318199dbc3.
43. Rosenberg SL, Miller GE, Brehm JM, Celedón JC. Stress and asthma: Novel insights on genetic, epigenetic, and immunologic mechanisms. *Journal of Allergy and Clinical Immunology*. 2014;134(5):1009-1015. http://www.ncbi.nlm.nih.gov/pubmed/25129683. doi: 10.1016/j.jaci.2014.07.005.
44. Gupta RS, Zhang X, Springston EE, et al. The association between community crime and childhood asthma prevalence in Chicago. *Annals of Allergy, Asthma & Immunology*. 2010;104(4):299-306. http://www.sciencedirect.com/science/article/pii/S1081120609000507. doi: 10.1016/j.anai.2009.11.047.
45. Butz AM, Ogborn J, Mudd S, et al. Factors associated with high short-acting β2-agonist use in urban children with asthma. *Annals of allergy, asthma & immunology : official publication of the American College of Allergy, Asthma, & Immunology*. 2015;114(5):385-392. http://www.ncbi.nlm.nih.gov/pubmed/25840499. doi: 10.1016/j.anai.2015.03.002.
46. Sampson RJ, Morenoff JD, Gannon-Rowley T. Assessing "Neighborhood effects": Social processes and new directions in research. *Annual Review of Sociology*. 2002;28(1):443-478. doi: 10.1146/annurev.soc.28.110601.141114.
47. Baltimore Neighborhood Indicators Alliance- Jacob France Institute. Vital signs 13. . Updated 2015.
48. ESRI. ArcGIS desktop: Release 10. . 2010.
49. Jackson RD, Huete AR. Interpreting vegetation indices. *Preventive Veterinary Medicine*. 1991;11(3):185-200. http://www.sciencedirect.com/science/article/pii/S0167587705800042. doi: 10.1016/S0167-5877(05)80004-2.
50. Dadvand P, de Nazelle A, Figueras F, et al. Green space, health inequality and pregnancy. *Environment International*. 2012;40:110-115. http://www.sciencedirect.com/science/article/pii/S0160412011001905. doi: 10.1016/j.envint.2011.07.004.
51. United States Department of Justice. Federal bureau of investigation: Uniform crime reporting statistics: UCR offense definitions. . Updated 2016.

52. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology*. 1986;51(6):1173-1182. http://www.ncbi.nlm.nih.gov/pubmed/3806354. doi: 10.1037/0022-3514.51.6.1173.
53. Doolan DM, Froelicher ES. Using an existing data set to answer new research questions: A methodological review. *Research and theory for nursing practice*. 2009;23(3):203. http://www.ncbi.nlm.nih.gov/pubmed/19769213.
54. Owens A. Inequality in children's contexts: Income segregation of households with and without children. *American Sociological Review*. 2016;81(3):549. https://search.proquest.com/docview/1796784995. doi: 10.1177/0003122416642430.
55. Wen M, Zhang X, Harris C, Holt J, Croft J. Spatial disparities in the distribution of parks and green spaces in the USA. *ann behav med*. 2013;45(S1):18-27. http://www.ncbi.nlm.nih.gov/pubmed/23334758. doi: 10.1007/s12160-012-9426-x.
56. Camacho-Rivera M, Kawachi I, Bennett GG, Subramanian SV. Perceptions of neighborhood safety and asthma among children and adolescents in Los Angeles: A multilevel analysis. *PloS one*. 2014;9(1):e87524. http://www.ncbi.nlm.nih.gov/pubmed/24466355. doi: 10.1371/journal.pone.0087524.
57. Juniper EF, Gruffydd-Jones K, Ward S, Svensson K. Asthma control questionnaire in children: Validation, measurement properties, interpretation. *The European respiratory journal*. 2010;36(6):1410-1416. http://www.ncbi.nlm.nih.gov/pubmed/20530041. doi: 10.1183/09031936.00117509.
58. Martinez ML, Black M, Starr RH. Factorial structure of the perceived neighborhood scale (PNS): A test of longitudinal invariance. *Journal of Community Psychology*. 2002;30(1):23-43. http://onlinelibrary.wiley.com/doi/10.1002/jcop.1048/abstract. doi: 10.1002/jcop.1048.
59. Chang MY, Hogan AD, Rakes GP, et al. Salivary cotinine levels in children presenting with wheezing to an emergency department. *Pediatric Pulmonology*. 2000;29(4):257. doi: AID-PPUL4>3.3.CO;2-M.
60. Hukkanen J, Jacob III P, Benowitz NL. Metabolism and disposition kinetics of nicotine. *Pharmacological Reviews*. 2005;57(1):79-115. http://pharmrev.aspetjournals.org/content/57/1/79.abstract. doi: 10.1124/pr.57.1.3.
61. Bernert JT, McGuffey JE, Morrison MA, Pirkle JL. Comparison of serum and salivary cotinine measurements by a sensitive high-performance liquid chromatography-tandem mass spectrometry method as an indicator of exposure to tobacco smoke among smokers and nonsmokers. *Journal of Analytical Toxicology*. 2000;24(5):333-339. http://www.ncbi.nlm.nih.gov/pubmed/10926356. doi: 10.1093/jat/24.5.333.
62. Salimetrics. *High sensitivity salivary cotinine technical performance characteristics.* State College, PA: Salimetrics; 2007.
63. The Regents of the University of California, MacArthur Foundation. Research: Social environmental notebook. . Updated 2008.

Figure 2. Map of Baltimore City separated into Community Statistical Areas. The map includes the approximate location of each study participant and the symbol indicates the child's level of asthma control.

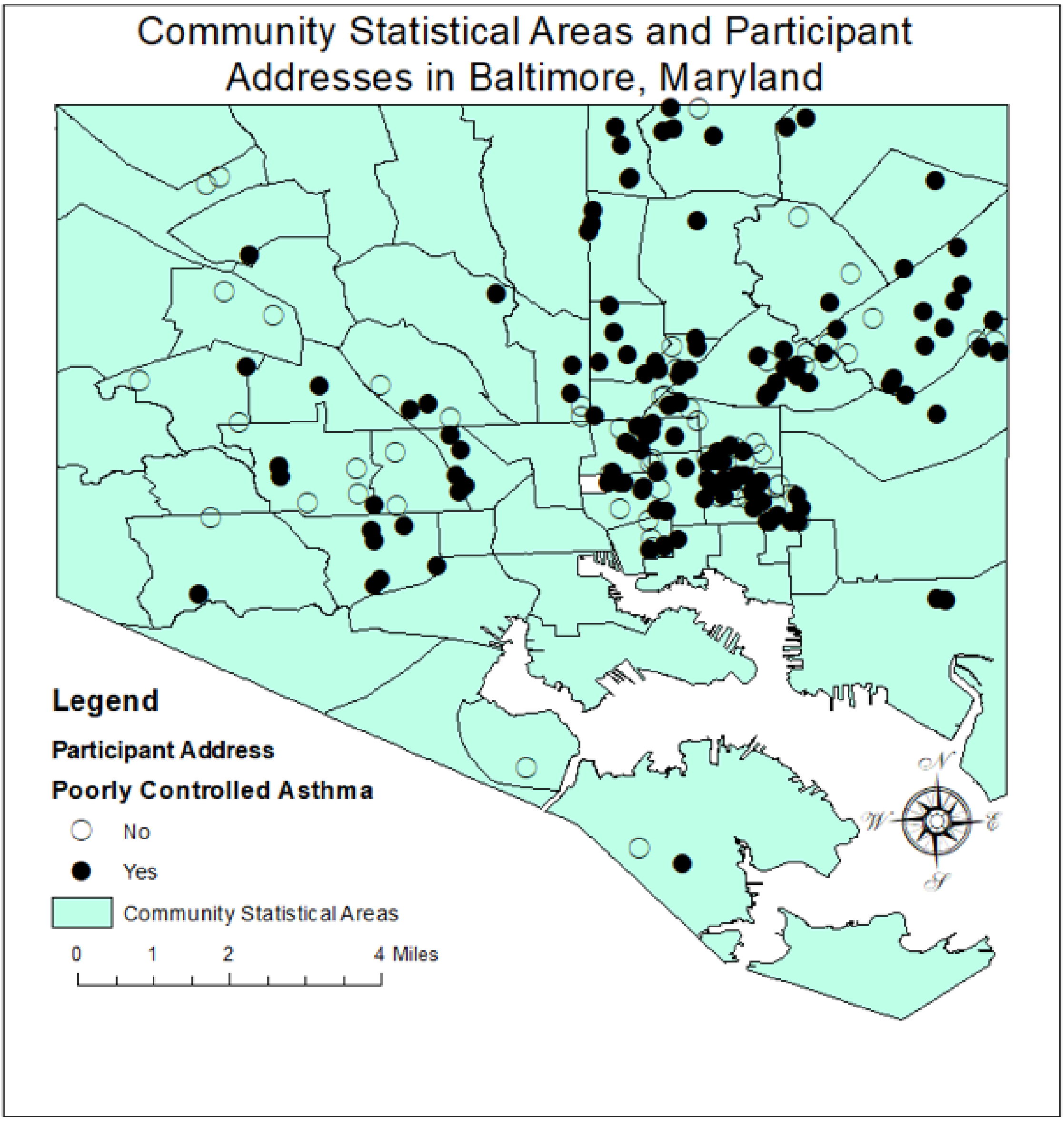

Table 1. Variables and Measures. This table includes the dependent and independent variables along with potential covariates. The table also describes variable operationalization, whether the data will be added for this study ("New Data") or came from the parent study ("Existing Data") and the informant or source of the data.

Variable	Measurement	New (N) or Existing (E) Data	Informant/ Source
Dependent:			
Asthma Control- Aim 1, 2, and 3	Binary; poorly controlled (yes/no): Asthma Control Questionnaire test-retest reliability r=0.77; criterion validity demonstrated by significant associations with clinicians' ratings of asthma control r=0.72[57]	E	Parent
Independent:			
Greenspace – Aim 1 and 3	Continuous: Normalized Difference Vegetation Index (NDVI) Measure of proportion of ground covered by green vegetation[49] in each Community Statistical Area (CSA)	N	United States Geological Survey
Neighborhood Violent Crime Rate- Aim 2 and 3	Continuous: Violent crime rate: homicide, rape, aggravated assault, and robbery in Baltimore City that are reported to the Police Department. Incidents are per 1,000 residents in the CSA.	N	Baltimore City Police Department
Parent Perception of Neighborhood Safety- Aim 2 and 3	Continuous: Subscale of the Perceived Neighborhood Scale,[58] (9 questions on a Likert scale). Alpha reliability for this subscale for the study sample =0.928	E	Parent
Asthma Triggers and Allergic Sensitization:			
Allergic Sensitization	Dichotomous: Radioallergosorbent test (RAST) test: 5ml blood. Venipuncture by PEDS ED nurse or Patient care tech. Test will develop allergen sensitization profile	E	Physiologic
Child exposure to secondhand smoke (SHS)	Dichotomous: 1ml saliva, collected using sorbettes and swabs Salivary Cotinine Level[59-62] <1.0 ng/ml=non to low exposure ≥ 1.0 ng/ml=positive cotinine	E	Physiologic
Presence of Pests in Home	Dichotomous: Ask parent if they have seen roaches, rats, or mice in their home in the past three months.	E	Parent
Covariates:			
Demographics: **Parent:** age, education, marital status, race/ethnicity **Child:** age, sex, race/ethnicity	Baseline Demographic Questionnaire- Age- Continuous, Education- Categorical, Marital Status- Categorical, Sex- Dichotomous, Race/Ethnicity- Categorical	E	Parent
Income	Categorical- Combined Family income[63]	E	Parent
Season of enrollment	Categorical	E	N/A

Table 2. Detectable Odd Ratios based on predictor distributions and intra-class correlation of Asthma Control Level across CSAs.

Predictor distribution[a]	Intraclass Correlation Coefficient (ICC)		
	.10	.15	.20
10/90	3.58	3.84	4.12
30/70	2.32	2.42	2.53
50/50	2.17	2.26	2.35

[a] Potential distribution of high versus low greenspace or high versus low violent crime rate

CHAPTER 4: MANUSCRIPT FOUR: Is green(space) always good? Examining the association between neighborhood greenspace and children's asthma control in an urban city

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Abstract

Objectives: Racial and socioeconomic disparities in childhood asthma have been partially attributed to differential neighborhood exposures associated with poverty. Greenspace, or land with grass, trees or other vegetation, is a modifiable neighborhood exposure that may improve asthma control. However, living in unsafe neighborhoods may limit the potential benefits of greenspace. This study examined the associations among neighborhood greenspace, neighborhood violence, and asthma control in a sample of low-income, predominantly African American children diagnosed with uncontrolled asthma in Baltimore. Primary hypotheses were: 1) more neighborhood greenspace would be associated with better asthma control; 2) more neighborhood violence would be associated with poorer asthma control; and 3) neighborhood violence would moderate the relationship between greenspace and level of asthma control.

Study Design: This cross-sectional study built on an existing study of children (age 3-12) with uncontrolled asthma living in Baltimore (n=196). Multivariable logistic regression models were used to test study hypotheses, controlling for demographic, social, and environmental risk factors.

Results: Most of the sample children were African American (95%), male (65%), insured by Medicaid (95%), exposed to secondhand smoke (59%), and diagnosed with very poorly controlled asthma (55%). Overall the hypotheses were not supported, but additional analyses demonstrated significant interactions between secondhand smoke and exposure to greenspace and violence.

Conclusions: This study demonstrates the complexity of measuring neighborhood factors and their relationships. Future research in this area should incorporate a larger sample size with greater variability and a longitudinal design.

Abbreviations:

NDVI: Normalized difference vegetation index

NWC: Not well controlled

VPC: Very poorly controlled

Introduction

Over 6 million children[1] in the United States have asthma, a chronic disease estimated to cost $81.9 billion annually in healthcare expenditures, absenteeism, and mortality.[2] Among children with asthma, 38% have uncontrolled asthma defined as having one or more of the following: two or more symptom days per week, more than one symptom night per month, rescue medication use more than twice a week, or asthma-related symptoms causing significant limitations in daily activities.[3] This lack of symptom control leads to poorer quality of life, increased pediatric emergency department visits and hospitalizations, and a disproportionately higher burden of healthcare expenditures. The incidence of uncontrolled asthma is not equally distributed. Children from economically disadvantaged families and racial and ethnic minority groups are more likely to have uncontrolled asthma. In a 2016 Centers for Disease Control and Prevention report on children with asthma, 21% of children living below the federal poverty line had a pediatric emergency department visit compared to 11.3% of children who live between 250% to <450% of the federal poverty line.[2] In that same report, Black, non-Hispanic children were almost twice as likely to have an asthma-related pediatric emergency department visit as White, non-Hispanic children (22.5% vs. 12.2%, respectively).[2]

Disparities in asthma burden have been attributed to differential exposures to growing up in poverty, living in unsafe and stressful neighborhoods,[4] and unhealthy physical environments (e.g., air pollution,[5-9] presence of pests in the home,[10] and secondhand smoke exposure[11]). One potentially modifiable factor that may improve asthma control is the availability of neighborhood greenspace. Defined as land with grass, trees, or other vegetation,[12] greenspace has been associated with increased physical activity[13] and decreased stress,[14,15] environmental heat, and air pollution,[16] all variables associated with improved asthma control in children.[17-20]

However, the impact of greenspace on pediatric asthma control remains unclear. Some studies have shown that increases in the normalized difference vegetation index (NDVI), a measure of the greenspace in a given geographical area, is associated with decreased asthma prevalence.[13] However, other studies have shown no effects[21] or negative effects[22] of greenspace on asthma prevalence and control. One possible explanation for the mixed results is the failure to account for neighborhood level contextual factors that might influence children's exposure to greenspace, such as neighborhood violence. Living in an unsafe neighborhood has been associated with greater stress and children spending less time in greenspace,[23,24] resulting in increased exposure to indoor allergens and irritants, including second hand smoke.[25] Research has demonstrated that children living in areas with high violent crime have poorer asthma control than those living in areas with low violent crime.[26]

The current study analyzed data from a predominantly African American and Medicaid insured sample of urban living children with uncontrolled asthma. The purpose of the study was to understand whether the availability of neighborhood greenspace was associated with better asthma control in this highly vulnerable population of children and the extent to which neighborhood violence might modify that relationship by limiting children's ability to take advantage of that greenspace. Three hypotheses were posed; (1) children living in areas with more neighborhood greenspace would have better asthma control compared to children living in areas with less neighborhood greenspace; (2)

children living in neighborhoods with higher violent crime victimization rates would have poorer asthma control compared to children living in neighborhoods with lower rates; (3) violent crime victimization rates would modify the relationship between greenspace and level of asthma control such that living in neighborhoods with higher neighborhood violence rates (relative to others in the sample) would weaken the association between more neighborhood greenspace and better asthma control.

Methods

This cross-sectional study builds on an existing data set from a larger study of children with uncontrolled asthma recruited from August 2013 through February 2016 from the Johns Hopkins Hospital Pediatric Emergency Department following an asthma exacerbation.[27] Parents provided written informed consent and children 8 years and older provided verbal assent. This study was approved by the Johns Hopkins Hospital Institutional Review Board.

Inclusion criteria for the larger study were that the parent was the legal guardian of a child 3-12 years old who had a history of two or more asthma related pediatric emergency department visits or one asthma-related hospitalization over the past 12 months, spoke English, could read at a fourth-grade level, had access to a working phone for follow-up surveys, and resided in the Baltimore metropolitan area. Children were excluded if they had a co-morbid respiratory condition, were participating in another asthma-related study at the time of enrollment or were in foster care where consent could not be obtained by a legal guardian. Only children living in Baltimore City at the time of enrollment were included in the current study, excluding 26 children from the larger study (see Figure 1).

Level of asthma control, categorized as not well controlled (NWC) or very poorly controlled (VPC), was the primary outcome variable. Using national asthma guidelines, level of asthma control was based on report of number of symptom days over the past two weeks, number of symptom nights over the past four weeks, activity limitation over the past week, and short-acting β_2-agonist use over the past two weeks.[3] Using these variables, an algorithm was created to calculate each child's level of asthma control as NWC or VPC, with VPC defined as the poorer outcome. Parents reported this information during enrollment into the larger study.

The child's home address provided at the time of enrollment was used to estimate neighborhood-level variables. Neighborhood greenspace and violence rates were estimated for the areas surrounding this home address, as described below.

Neighborhood greenspace was measured using the normalized difference vegetation index (NDVI) which ranges from -1 to 1 with higher numbers representing areas with more green vegetation.[28] NDVI was derived from satellite data obtained from the United States Geological Survey (https://lta.cr.usgs.gov/LETMP) at 30m by 30m resolution for the Baltimore City region and calculated by pixel using the geospatial referencing software, ArcGIS version 10.5.1.[29] The average NDVI within a 100m radius of each child's home address was calculated. NDVI was treated as a continuous and categorical variable, dichotomized along the median to represent areas with low versus high neighborhood greenspace and aid with interpretation of interactions. To calculate NDVI, the satellite image from April 2013 was chosen because it was clear with limited cloud cover over the desired location. Although April is earlier than the start of recruitment in August 2013, research demonstrates that measurement of NDVI is consistent across several years.[30]

Neighborhood violence was measured using the violent crime victimization rate per 1,000 residents in a census tract. Open source, victim-based crime data were obtained from the Baltimore City Police Department (https://data.baltimorecity.gov/). These data were downloaded from 2013-2015 and filtered to include violent crime victimizations per the Federal Bureau of Investigation's Uniform Crime Reporting Program comprising homicide/manslaughter, rape, aggravated assault, and robbery.[31] Reported home address was used to determine the child's census tract and the year of violent crime victimizations ascribed to each child was based on study enrollment date. Violent crime victimization rate was treated as a continuous and categorical variable, dichotomized along the median to represent areas with high versus low neighborhood violence.

Children's age, sex, race, parental age, season at enrollment, allergen sensitization, secondhand smoke exposure, asthma medication use, and social risk were assessed to address potential sources of confounding. This data was collected during enrollment into the larger study. Parents provided information on their socio-demographic background and the child's asthma medication use. Children's blood and saliva samples were collected to determine allergen sensitization and secondhand smoke exposure, respectively. We created an index of social risk to capture the number of socio-economic and psychosocial risk factors that might affect family wellbeing: highest level of parent education was a high school diploma (or General Education Diploma) or less,[32,33] child living in a single-parent household,[34] Medicaid insured, parent was unemployed,[33] four or more children living in the home,[34] parent had an elevated risk for depression based on a score of 16 or more on the Centers for Epidemiological Studies Depression (CESD) Scale,[32,35] if they have lived one year or less in their current home,[33] and if they perceived their neighborhood as having a weak "sense of community" based on the lowest quartile of scores reported on the "Sense of Community" domain of the Perceived Neighborhood scale."[36] Social risk scores could range from 0 to 8, with higher scores indicating greater social risk.

Allergen sensitization was measured using 5 ml of blood to test serum specific IgE antibodies to ten common environmental allergens classified as indoor (mouse, cockroach, cat, dog, *aspergillus* mold, and house dust mite) and outdoor (timothy grass, a*lternaria* mold, oak tree, and common ragweed). Samples were analyzed in a commercial lab using fluorescent enzyme immunoassay and results > 0.35 kU/L were considered positive. Atopy or sensitization to either indoor or outdoor allergens was positive if they had at least one positive sensitization to an allergen in that category.

Secondhand smoke exposure was measured using children's saliva to determine salivary cotinine concentration, a biomarker for the child's level of nicotine exposure in the past 24-48 hours. Positive secondhand smoke exposure was based on a salivary cotinine cutoff level $\geq$ 1.0 ng/ml.[37]

Medication use was based on the asthma medication ratio, a ratio of total number of controller medication canisters divided by the total number of controller and rescue medication canisters over the previous 12-months. Number of medication canisters were obtained for each child through pharmacy dispensing records and used to calculate the asthma medication ratio. The ratio was dichotomized to $\geq$0.5 versus <0.5. An asthma medication ratio of 0.50 or higher is associated with receiving guideline-based care leading to decreased asthma morbidity and emergency department use and an asthma medication ratio < 0.5 is associated with increased morbidity.[38,39]

Statistical Analysis

The power analysis is based on preliminary analysis of the original data set. Based on a literature review, it was assumed that the variable of NDVI would be skewed. Therefore, NDVI would be dichotomized as low or high. Of the 196 children, 55% had VPC asthma and 45% have NWC asthma. This rate was used for the outcome to determine the odds ratio detectable with statistical power of .80, alpha level of .05, and N=196. With the dichotomous NDVI predictor variable distribution of 50/50, the detectable odds ratio is 2.33.

Descriptive statistics were initially examined for all variables along with patterns of missing data. The measures missing data were the asthma medication ratio (11% missing), social risk index (8% missing), outdoor allergen sensitization (10% missing), indoor allergen sensitization (11% missing), and secondhand smoke exposure (6% missing). To assess whether there were systematic differences between those with and without missing data, a comparison was done on baseline variables. No significant differences were found for child age, sex, season at baseline, and neighborhood greenspace. Data on the asthma medication ratio and social risk index were multiply imputed with 10 datasets using the Markov Chain Monte Carlo method.[40,41] Consistent with epidemiologic studies,[42] biologic data were not imputed but analyzed using complete case analysis.

The unadjusted associations between each covariate were evaluated with the outcome measure, level of asthma control. Next, multivariable regression models were tested to predict level of asthma control (NWC vs. VPC). The covariates that were theoretically important or demonstrated statistical significance at a trend level ($p<0.10$) were included in the first models. The initial multivariable logistic regression models contained covariates and the independent variable of greenspace (Table 2) or violent crime victimization rate (Table 3) as predictors of level of asthma control (NWC vs. VPC). Using backward elimination, covariates that were not significant at the trend level ($p=0.10$) were removed, starting with those that had the smallest effect. The fit of the models was compared with the C-statistic. An interaction term between the main predictor (greenspace or violence) and secondhand smoke exposure was added based on previous literature.[43] Semivariograms of the standardized regression residuals of the final models were estimated to assess assumptions of spatial independence.

To test the third hypothesis that neighborhood violence moderates the relationship between greenspace and level of asthma control, an interaction term was created for greenspace with neighborhood violence. As the study was under powered to test moderation, additional analyses were conducted to explore effect sizes associated with differing strata of neighborhood violence. Specifically, violent crime victimization rate was trichotomized based on the lowest, middle, and highest third of violent crime victimization rates (see Table 4). The magnitude of the odds ratios was then compared across the three strata.

All calculations were done in Stata version 15.1.[44] Statistical significance was set at $p<0.05$. Sensitivity analyses demonstrated that results were consistent between the dataset with imputed variables (asthma medication ratio and social risk index) (n=167) and complete case data (n=136) therefore imputed data is presented to maximize statistical power. To assess if housing instability may have influenced relationships, a sensitivity analysis was run controlling for reported length of time in the neighborhood.

Results

As shown in Table 1, of the 196 children for the current study 128 were male (65%), 186 were African American (95%), and 186 were Medicaid insured (95%). Out of the parents, 151 were single (78%) and 182 were the child's biological mother (93%).

The distribution of health covariates of the sample is summarized in Table 1. Ninety-two children (53%) had an asthma medication ratio greater than 0.50. One hundred forty-five children of the sample were sensitized to at least one indoor allergen (83%) and 109 were sensitized to at least one outdoor allergen (62%). One hundred and seven children (55%) had VPC asthma and 109 were exposed to second hand smoke (59%).

NDVI values were positively skewed with a median of 0.06 (Interquartile range [IQR] 0.04, 0.09) and mean of 0.07 (standard deviation [SD] 0.04). The index ranged from 0.00 to 0.17. After initial analysis treating NDVI as a continuous variable, to test moderation NDVI was dichotomized along the median to represent areas with high versus low greenspace.

Violent crime victimization rate was normally distributed with a median of 20.46 (IQR 13.09, 26.47) and mean of 20.75 (SD 9.74). Rates ranged from 4.94 to 52.23 violent crime victimizations per 1,000 residents in the census tract.

As displayed in Tables 2 and 3, results of the analyses of bivariate relationships showed that those with an asthma medication ratio of 0.50 or greater were significantly more likely to have VPC asthma compared to those with an asthma medication ratio less than 0.50 (OR 2.20; 95% CI [1.20, 4.05]). This suggests that children with very poorly controlled asthma were prescribed more controller medications than those with not well controlled asthma. There were no significant relationships between level of asthma control and amount of greenspace as measured by NDVI (Table 2) or violent crime victimization rate (Table 3).

A series of multiple regression models were used to test the first hypothesis that children living in areas with more neighborhood greenspace would have better asthma control compared to children living in areas with less neighborhood greenspace. In model 1 (Table 2) asthma medication ratio remained significantly associated with level of asthma control after adjusting for social risk, season, outdoor allergen sensitization, secondhand smoke exposure, and greenspace (adjusted odds ratio [aOR] 2.41; 95% CI [1.18, 4.94]). The final model (Model 2) included social risk, season, asthma medication ratio, outdoor allergen sensitization, secondhand smoke exposure, greenspace, and an interaction between greenspace and secondhand smoke exposure. Two covariates were significantly associated with level of asthma control in this model; the asthma medication ratio (aOR 2.86; 95% CI [1.34, 6.10]) and outdoor allergen sensitization (aOR 0.47; 95% CI [0.23, 0.96]). The interaction between greenspace and secondhand smoke exposure was statistically significant ($p=0.002$). To interpret this interaction, the sample was stratified by secondhand smoke exposure. Among children exposed to secondhand smoke ($n=98$), residing in a high greenspace neighborhood was associated with a lower likelihood of having VPC asthma (aOR= 0.39; 95% CI [0.15, 1.02]), but among children who were not exposed to secondhand smoke ($n=69$), residing in a high greenspace neighborhood was associated with a higher likelihood of having VPC asthma (aOR 2.43;

95% CI [0.78, 7.61]). While the stratified analyses were not statistically significant they are included to present the directions of associations between greenspace and asthma control. Overall, the first hypothesis was not supported but additional analyses indicate a significant interaction between secondhand smoke and greenspace.

The second hypothesis was tested next; whether children living in neighborhoods with higher violence would have poorer asthma control compared to children living in neighborhoods with lower violence. In the first model (Table 3), the asthma medication ratio remained significantly associated with level of asthma control after adjusting for social risk, season, outdoor allergen sensitization, secondhand smoke exposure, and violence (aOR 2.41; 95% CI [1.18, 4.96]). The final model (Model 2) included social risk, season, asthma medication ratio, outdoor allergen sensitization, secondhand smoke exposure, violence, and an interaction between violence and secondhand smoke exposure. The asthma medication ratio was the only covariate significantly associated with level of asthma control in this model (aOR 2.83; 95% CI [1.35, 5.93]). The interaction between violence and secondhand smoke exposure was significant (p=0.004). To interpret this interaction, the sample was stratified by secondhand smoke exposure. Among children exposed to secondhand smoke (n=98), the likelihood of having VPC asthma increased for every point increase in neighborhood violence (aOR= 1.03; 95% CI [0.99, 1.08]). Among children not exposed to secondhand smoke (n=69), the likelihood of having VPC asthma decreased for every point increase in neighborhood violence (aOR 0.97; 95% CI [0.91, 1.04]). However, neither of the results were statistically significant.

After development of the models to test hypotheses one and two, a semivariogram of the residuals indicated that the assumptions of spatial independence were upheld. Figure 2 presents the semivariogram for testing the null and full models for hypothesis one. For this sample, the median length of time children lived at their current address was two years. In a sensitivity analysis controlling for reported length of time in the neighborhood the results remained the same. This demonstrates that housing instability did not appear to influence relationships in this sample.

To test the third hypothesis that neighborhood violence modified the relationship between greenspace and level of asthma control an interaction term between violence and greenspace was added into a logistic regression model. In this model, violence was not found to moderate the relationship between greenspace and level of asthma control. Violence was trichotomized in further analyses based on the lowest, middle, and highest third of violent crime victimization rates (Table 4) to analyze for patterns in the effect size as opposed to analyzing for statistical significance. For children living in neighborhoods with the highest violent crime rate, more greenspace was associated with a lower likelihood of having VPC asthma compared to children living in areas with less greenspace (OR 0.89; 95% CI [0.29, 2.73]). However, among children living in neighborhoods with the lowest violent crime rate, more neighborhood greenspace was associated with a greater likelihood of having VPC asthma (OR 2.29; 95% CI [0.58, 9.08]). For children living in neighborhoods the middle strata of violent crime, those living in areas with more greenspace were less likely to have VPC asthma than those in areas with less greenspace (OR 0.62; 95% CI [0.23, 1.68]). Given the lack of a consistent pattern of relationships between neighborhood greenspace and asthma control found by level of neighborhood violent crime rate, the results do not support the third hypothesis that neighborhood violence modified the relationship between greenspace and asthma control in this sample of children.

Discussion

This study sought to understand the relationships among asthma control, neighborhood greenspace, and neighborhood violence in a sample of children with asthma living in low-income urban communities. The results show that in this sample, availability of greenspace was not related to children's asthma control, and neighborhood violence did not moderate this relationship. While none of the hypotheses were supported, there were significant interactions between secondhand smoke exposure and neighborhood greenspace and violent crime victimization rates, suggesting a need for additional research in this area. Below is a discussion of the study findings, limitations that may have led to these results, and recommendations for future research.

While this study was not designed to test the impact of secondhand smoke on asthma control or its effect on greenspace and violence, the significant interactions between secondhand smoke and neighborhood factors should be further explored. Secondhand smoke is a pervasive airway irritant that has been found to exacerbate asthma symptoms across all populations living with asthma. According to the CDC in 2012, those living below the poverty line (43.2% versus 21.2% for those above the poverty line) and Black, non-Hispanic children (67.9% compared to 37.2% of White, non-Hispanic children) are the most likely to be exposed to secondhand smoke.[45] Our sample of predominantly African American children reflects this data in that 59.2% tested positive for secondhand smoke exposure using a conservative salivary cotinine cutoff of 1.0 ng/ml. While it is clear that secondhand smoke exposure negatively impacts children with asthma, it is unclear how secondhand smoke exposure may be involved in the mechanisms through which greenspace and violence might influence asthma control. Given the findings of a significant interaction between secondhand smoke exposure and neighborhood greenspace and violent crime victimization rates, further research is warranted.

In the final models, two covariates, the asthma medication ratio and outdoor allergen sensitization were statistically significantly associated with level of asthma control. Children with an asthma medication ratio of at least 0.5 were more likely to have VPC asthma. This finding is theoretically intuitive in that the children with worse asthma control are on higher doses of controller medication.

This study did not demonstrate that neighborhood violence moderated the relationship between neighborhood greenspace and level of asthma control and additional analyses did not reflect a trend towards moderation. These null results align with a 2017 study by Feng and colleagues which did not find any associations when testing an interaction between greenspace and lack of area safety as they related to children's asthma diagnosis in Australia.[48] While our study addressed limitations of this work by using NDVI and neighborhood crime statistics to measure greenspace and neighborhood violence, it could be that due to limitations in these measures our findings did not support hypothesized moderation.

Overall, this study did not demonstrate that more neighborhood greenspace is associated with better asthma control. While NDVI is an objective and validated measure of neighborhood greenspace, there are limitations to its use. NDVI measures quantity of green vegetation but it does not measure characteristics of greenspace that may make them healthier spaces for children. For example, NDVI does not distinguish between a vacant lot that is overgrown with weeds or a neighborhood park with a playground and benches that may encourage physical activity and psychological restoration, two pathways through which greenspace improves health. The null findings in this study could be due to the inability to measure these nuanced qualities of greenspace that may relate to specific mechanisms through which greenspace influences health. A recent study linking greenspace to reduced stress, presented a survey strategy that might be a stronger measure for greenspace exposure.[46] The survey asked individuals about both visual and physical exposure to greenspace in three areas: near the home; near their work or school; and during recreation; and the weekly duration of all exposures. This measure of greenspace would improve on the limitations of using NDVI and should be considered in future research.

This study highlights the complexities of relationships between neighborhood variables. While there are clearly proposed mechanisms through which greenspace and safety may influence children's asthma, these theories need further development to accommodate additional variables (e.g. secondhand smoke exposure) and interrelationships between variables (e.g. correlations between greenspace and safety). There is a large body of research demonstrating that greenspace disproportionately benefits predominantly white, affluent neighborhoods.[47] Greenspaces are not randomly located but reflect a larger neighborhood context. And therefore, these theories might also benefit from expanding their scope to broader determinants such as neighborhood racial characteristics and neighborhood level socioeconomic status.

Given that this study used a cross-sectional design, it is not possible to assume directionality to the associations between variables. It is possible that families moved to greener, less violent neighborhoods prior to enrollment in order to improve their children's asthma. Research demonstrates that lower income families have higher rates of housing instability,[49] therefore, it is possible that families did not live in their homes long enough to be affected by exposure to greenspace and violence. For this sample, however, the median length of time children lived at their current address was two years and sensitivity analyses indicated that controlling for length time in the neighborhood did not change the results.

This study used an existing sample of children recruited for a larger study on asthma control which may have introduced selection bias in that all children reported to the emergency department for their asthma care and the children all agreed to be enrolled in a randomized controlled trial. While this study controlled for a number of confounding variables, there were others that could not be included in the analyses because they had not been collected from the families. For example, including data on children's actual exposure to greenspace would have provided a more accurate picture of their true exposure. Neighborhood, defined in this study by census tract and buffer areas surrounding the child's home address, may not reflect how these families define their neighborhood nor does it account for time children spend with other family members or at school, which may be in different geographic areas. There can also be edge effects in that those living close to the edge of the census tract may perceive their neighborhood as encompassing more than one or several census tracts. Future research should ask parents and children about where they spend their time and how they define their neighborhoods, rather than using administrative boundaries to define neighborhoods.

Another limitation of using existing data is that the sample size cannot be increased. The power analysis demonstrated that sample size was sufficient to test the hypothesis in aim one, but the sample size was not adequate to test moderation. Therefore, future research should build on these preliminary findings using larger sample sizes in order to investigate potential moderation.

All of the children in this study had uncontrolled asthma, which may have limited our ability to detect differences between those with not well controlled and very poorly controlled asthma. The rationale for focusing on these two extreme groups of children was based on the fact that economically disadvantaged, African American children living with uncontrolled asthma experience the highest asthma burden and risk for asthma related death. However, this diminished variability between the two comparison groups may have biased results toward the null. Future studies should sample children with a wider range in levels of asthma control.

Despite its limitations, this study has several strengths. This study is innovative in its use of multiple methods and informants (geocoding, neighborhood crime statistics, parent reports, and physiologic measures) to understand how neighborhood factors are linked to asthma control for children who are predominantly African American and low-income. This study also includes neighborhood violence as a contextual factor that may modify the potential benefits of neighborhood greenspace for children with asthma. This study found that children's exposure to secondhand smoke affected the associations between their asthma control and neighborhood greenspace and violent crime victimization rates. Further research in this area should use primary, longitudinal data on a larger sample of children with more variability in their level of asthma control. This research is designed to inform public health policies and the development of interventions for achieving health equity and reducing the asthma burden on families living in urban poverty.

Table 1. Sample characteristics and univariate relationships with level of asthma control

Data reported as mean±SD or N(%). P value from t test, χ^2, or Fisher's exact test.

	Total Sample, n=196	Very Poorly Controlled Asthma n=107	Not Well Controlled Asthma n=89	P value
Sociodemographic Characteristics				
Child age, years	6.4 ±2.7	6.6±2.8	6.2±2.5	0.312
Child sex, male	128(65.3)	70 (65.4)	58 (65.2)	0.971
Child Race, African American	186(94.9)	103 (96.3)	83 (93.3)	0.649
White or Hispanic	4(2.0)	2 (1.87)	3 (3.37)	
Other	6(3.1)	2 (1.87)	3 (3.37)	
Biological mother	182(92.9)	100 (93.5)	82 (92.1)	0.409
Parent age, years (n=188)	31.4±7.7	31.4±7.2)	31.4±8.3	0.962
Social Risk Index[a] (n=184)	4.3±1.5	4.4±1.7	4.2±1.2	0.234
Covariates				
Season of enrollment, Fall	71(36.2)	36 (33.6)	35 (39.3)	0.449
Winter	52(26.5)	33 (30.8)	19 (21.4)	
Spring	39(19.9)	19 (17.8)	20 (22.5)	
Summer	34(17.4)	19 (17.8)	15 (16.9)	
Asthma Medication Ratio ≥ 0.50 (n=174)	92(52.9)	58 (62.4)	34 (42.0)	0.007
Secondhand smoke exposure[b] (+) (n=184)	109(59.2)	58 (55.8)	51 (63.8)	0.275
Indoor Allergen Sensitization[c] (n=175)	145(82.9)	74 (79.6)	71 (86.6)	0.219
Outdoor Allergen Sensitization[d] (n=176)	109(61.9)	53 (57.0)	56 (67.5)	0.153

[a.] Social Risk Index includes: high school graduate/GED or less, single-parent household, Medicaid insured, unemployed, ≥4 children living in the home, parent CESD score ≥16, if they have lived ≤ 1 year in their current home, and if they perceived their neighborhood as having a weak sense of community, scores range from 0-8 with higher scores indicating greater risk.

[b.] Secondhand smoke exposure + (salivary cotinine ≥1.00 ng/ml)

[c.] Indoor allergen sensitization + if IgE antibody >0.35 kU/L to ≥1 indoor allergen (mouse, cockroach, cat, dog, *aspergillus* mold, or house dust mite)

[d.] Outdoor allergen sensitization + if IgE antibody >0.35 kU/L to ≥1 outdoor allergen (timothy grass, *Alternaria* mold, oak tree, or common ragweed)

Table 2. Logistic Regression examining odds of Very Poorly Controlled (VPC) Asthma (n=167)

	Odds ratio (95% CI)		
Variable	Unadjusted relationships OR (95% CI)	Model 1 aOR (95% CI)	Model 2 Final Model aOR (95% CI)
Child age	1.06 (0.95, 1.18)		
Child sex (male)	1.25 (0.21, 7.68)		
Social Risk Index (SRI)	1.13 (0.93, 1.37)	1.18 (0.93, 1.50)	1.21 (0.94, 1.56)
Season @ Baseline: Fall	Ref	Ref	Ref
Winter	1.69 (0.81, 3.51)	1.25 (0.54, 2.92)	1.52 (0.63, 3.65)
Spring	0.92 (0.42, 2.02)	0.96 (0.40, 2.27)	1.09 (0.44, 2.66)
Summer	1.23 (0.54, 2.80)	0.81 (0.31, 2.12)	0.76 (0.28, 2.05)
Asthma Medication Ratio ≥0.50	2.20 (1.20, 4.05)*	2.41 (1.18, 4.94)*	2.86 (1.34, 6.10)**
Indoor Allergen Sensitization (yes)	0.60 (0.27, 1.36)		
Outdoor Allergen Sensitization (yes)	0.64 (0.35, 1.18)	0.56 (0.29, 1.11)	0.47 (0.23, 0.96)*
Secondhand Smoke (SHS) Exposure (+)	0.72 (0.39, 1.31)	0.55 (0.27, 1.10)	1.51 (0.59, 3.88)
Greenspace (high)	1.04 (0.59, 1.83)	1.07 (0.56, 2.05)	4.12 (1.38, 12.28)*
Interactions			
SHS Exposure X Greenspace			0.11 (0.03, 0.44)**

*p<0.05
**p<0.01

Table 3. Logistic Regression examining odds of Very Poorly Controlled (VPC) Asthma (n=167)

	Odds ratio (95% CI)		
Variable	Unadjusted relationships OR (95% CI)	Model 1 aOR (95% CI)	Model 2 Final Model aOR (95% CI)
Child age	1.06 (0.95, 1.18)		
Child sex (male)	1.25 (0.21, 7.68)		
Social Risk Index (SRI)	1.13 (0.93, 1.37)	1.18 (0.92, 1.51)	1.23 (0.95, 1.59)
Season @ Baseline: Fall	Ref	Ref	Ref
Winter	1.69 (0.81, 3.51)	1.26 (0.54, 2.93)	1.22 (0.52, 2.90)
Spring	0.92 (0.42, 2.02)	0.95 (0.40, 2.25)	1.13 (0.46, 2.80)
Summer	1.23 (0.54, 2.80)	0.81 (0.31, 2.13)	0.64 (0.23, 1.76)
Asthma Medication Ratio ≥0.50	2.20 (1.20, 4.05)*	2.41 (1.18, 4.96)*	2.83 (1.35, 5.93)**
Indoor Allergen Sensitization (yes)	0.60 (0.27, 1.36)		
Outdoor Allergen Sensitization (yes)	0.64 (0.35, 1.18)	0.56 (0.28, 1.11)	0.54 (0.27, 1.07)
Secondhand Smoke (SHS) (positive)	0.72 (0.39, 1.31)	0.55 (0.27, 1.11)	0.06 (0.01, 0.32)**
Violence[a]	1.01 (0.98, 1.04)	1.00 (0.97, 1.03)	0.93 (0.88, 0.99)*
Interactions			
SHS Exposure X Violence			1.11 (1.03, 1.20)**

[a] Violence measured as violent crime victimization rate per 1,000 people in a census tract
*p<0.05
**p<0.01

Table 4. Odds ratio of Very Poorly Controlled Asthma across three stratifications of Violence (n=196)

	Lowest tertile of Violent Crime Victimization Rate (n=63) OR (95% CI)	Middle tertile of Violent Crime Victimization Rate (n=64) OR (95% CI)	Highest tertile of Violent Crime Victimization Rate (n=69) OR (95% CI)
Greenspace (high)	2.29 (0.58, 9.08)	0.62 (0.23, 1.68)	0.89 (0.29, 2.73)

Figure 1. Recruitment, Randomization, and Retention Diagram

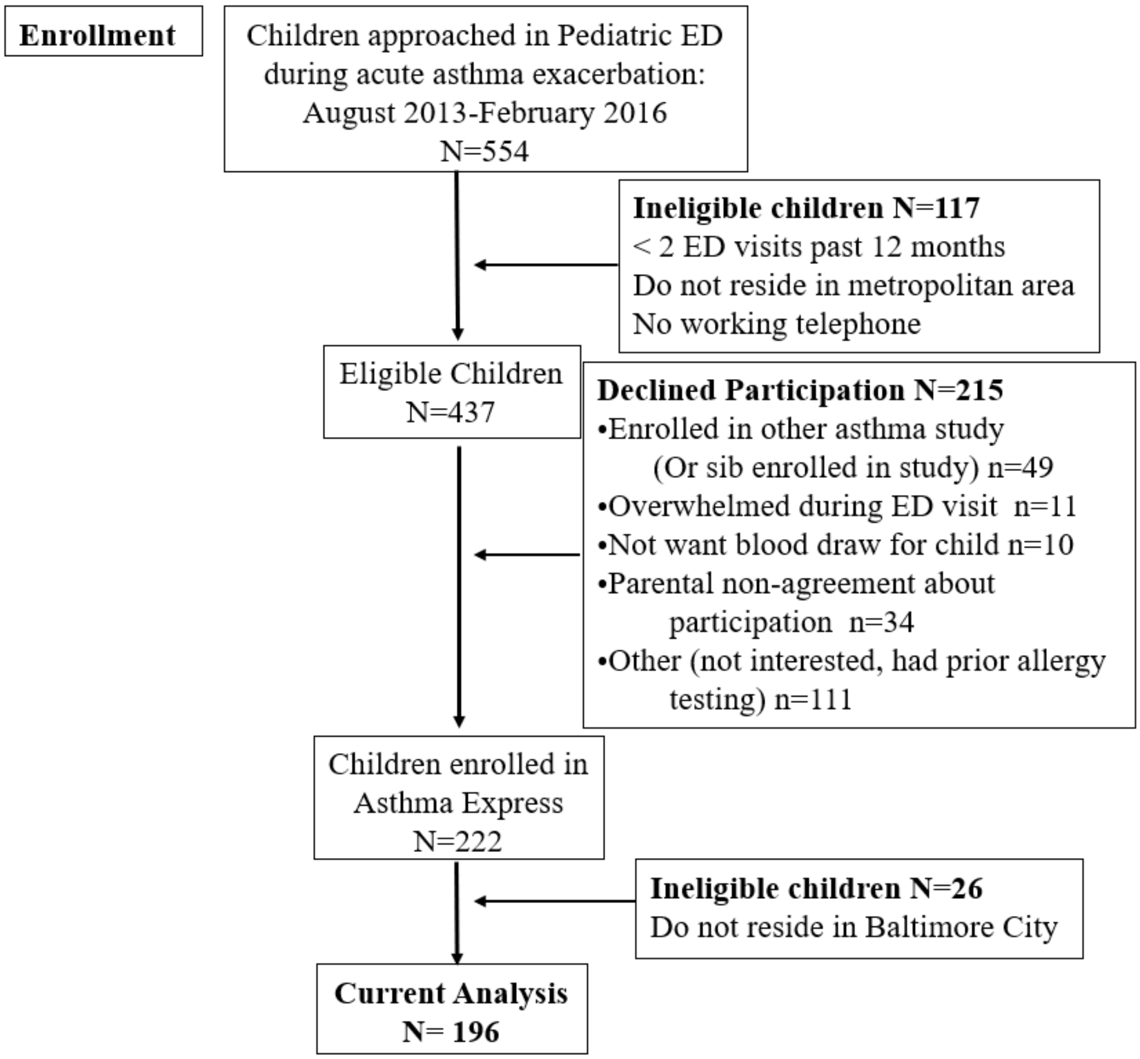
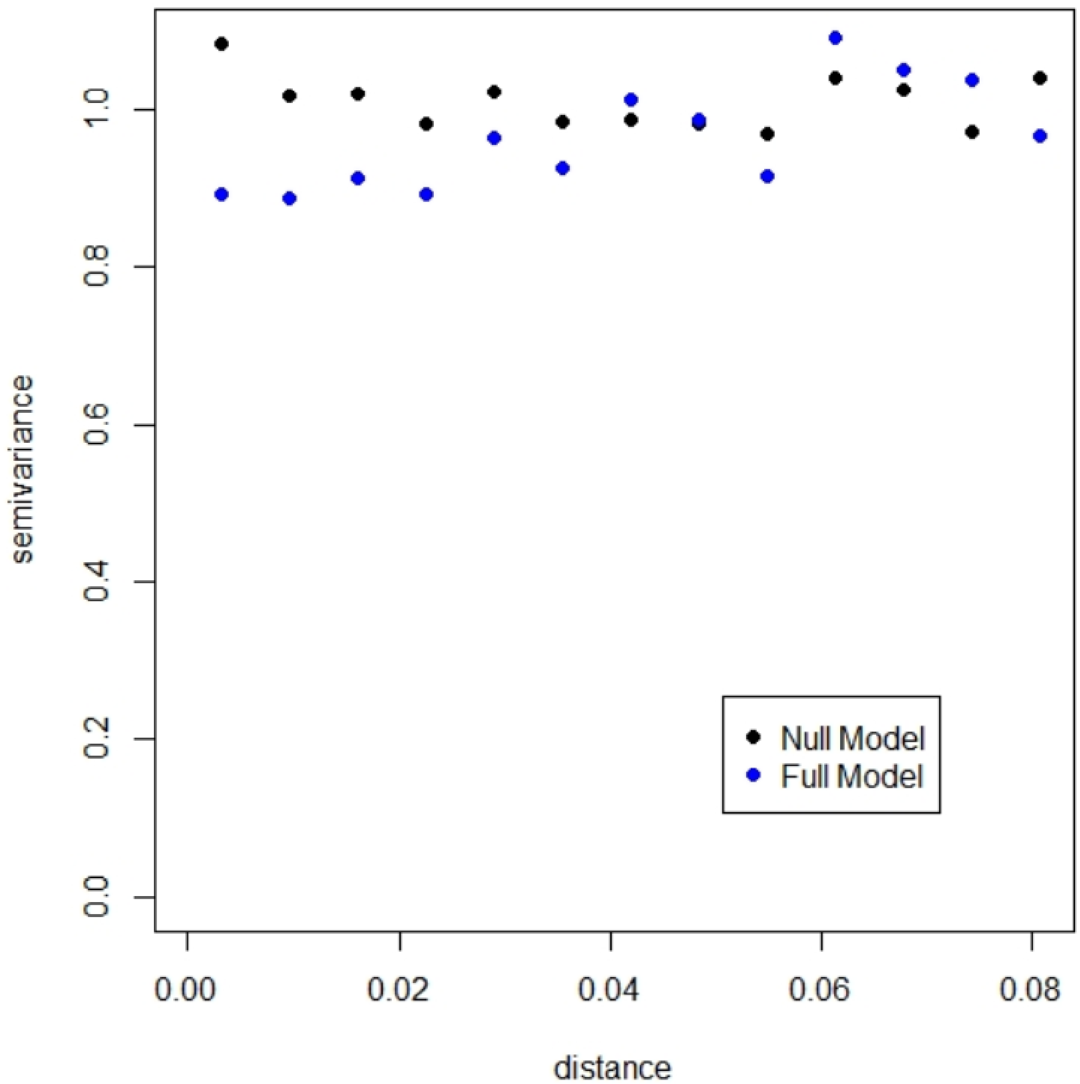


Figure 2. Residual Semivariograms: Null and Full Model



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References

1. Nurmagambetov T, Kuwahara R, Garbe P. The economic burden of asthma in the United States, 2008–2013. *Annals of the American Thoracic Society*. 2018;15(3):348-356. https://search.proquest.com/docview/2021667795. doi: 10.1513/AnnalsATS.201703-259OC.
2. Zahran H, Bailey C, Damon S, Garbe P, Breysse P. Vital signs: Asthma in children - United States, 2001-2016. *US Department of Health and Human Services/Centers for Disease Control and Prevention*. 2018:149-155.
3. U.S. Department of Health and Human Services, National Heart, Lung, and Blood Institute. The national asthma education and prevention program. expert panel report 3 (EPR3): Guidelines for the diagnosis and management of asthma. 2007.
4. Evans GW, Kim P. Childhood poverty, chronic stress, self-regulation, and coping. *Child Development Perspectives*. 2013;7(1):43-48. https://onlinelibrary.wiley.com/doi/abs/10.1111/cdep.12013. doi: 10.1111/cdep.12013.
5. Buonanno G, Marks GB, Morawska L. Health effects of daily airborne particle dose in children: Direct association between personal dose and respiratory health effects. *Environmental Pollution*. 2013;180:246-250. http://www.ncbi.nlm.nih.gov/pubmed/23792384. doi: 10.1016/j.envpol.2013.05.039.
6. Glad JA, Brink LL, Talbott EO, et al. The relationship of ambient ozone and PM(2.5) levels and asthma emergency department visits: Possible influence of gender and ethnicity. *Arch Environ Occup Health*. 2012;67(2):103-108.
7. Svendsen ER, Gonzales M, Mukerjee S, et al. GIS-modeled indicators of traffic-related air pollutants and adverse pulmonary health among children in El Paso, Texas. *Am J Epidemiol*. 2012;176 Suppl 7:131.
8. Vieira SE, Stein RT, Ferraro AA, et al. Urban air pollutants are significant risk factors for asthma and pneumonia in children: The influence of location on the measurement of pollutants. *Arch Bronconeumol*. 2012;48(11):389-395.
9. Li S, Batterman S, Wasilevich E, Elasaad H, Wahl R, Mukherjee B. Asthma exacerbation and proximity of residence to major roads: A population-based matched case-control study among the pediatric Medicaid population in Detroit, Michigan. *Environ Health*. 2011;10:34.
10. Olmedo O, Goldstein IF, Acosta L, et al. Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in New York City. *J Allergy Clin Immunol*. 2011;128(2):292.e7.
11. Butz A, Breysse P, Rand C, et al. Household smoking behavior: Effects on indoor air quality and health of urban children with asthma. *Matern Child Health J*. 2011;15(4):460-468.
12. US Environmental Protection Agency. What is open space/green space. https://www3.epa.gov/region1/eco/uep/openspace.html. Updated 2016.
13. Sbihi H, Tamburic L, Koehoorn M, Brauer M. Greenness and incident childhood asthma: A 10-year follow-up in a population-based birth cohort. *Am J Respir Crit Care Med*. 2015;192(9):1131-1133.
14. Yamaguchi M, Deguchi M, Miyazaki Y. The effects of exercise in forest and urban environments on sympathetic nervous activity of normal young adults. *The Journal of*

International Medical Research. 2006;34(2):152-159. doi: 10.1177/147323000603400204.
15. Hansmann R, Hug S, Seeland K. Restoration and stress relief through physical activities in forests and parks. *Urban Forestry & Urban Greening*. 2007;6(4):213-225. http://www.sciencedirect.com/science/article/pii/S1618866707000623. doi: 10.1016/j.ufug.2007.08.004.
16. Irvine KN, Warber SL, Devine-Wright P, Gaston KJ. Understanding urban green space as a health resource: A qualitative comparison of visit motivation and derived effects among park users in Sheffield, UK. *International journal of environmental research and public health*. 2013;10(1):417-442. http://www.ncbi.nlm.nih.gov/pubmed/23340602. doi: 10.3390/ijerph10010417.
17. Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A. *Environmental health : a global access science source*. 2016;15(1):57. http://www.ncbi.nlm.nih.gov/pubmed/27117324. doi: 10.1186/s12940-016-0142-z.
18. Tosca MA, Ruffoni S, Canonica GW, Ciprandi G. Asthma exacerbation in children: Relationship among pollens, weather, and air pollution. *Allergologia et Immunopathologia*. 2014;42(4):362-368. http://www.ncbi.nlm.nih.gov/pubmed/23755880. doi: 10.1016/j.aller.2013.02.006.
19. Fanelli A, Cabral ALB, Neder JA, Martins MA, Carvalho CRF. Exercise training on disease control and quality of life in asthmatic children. *Medicine and science in sports and exercise*. 2007;39(9):1474-1480. http://www.ncbi.nlm.nih.gov/pubmed/17805077. doi: 10.1249/mss.0b013e3180d099ad.
20. Marin TJ, Chen E, Munch JA, Miller GE. Double-exposure to acute stress and chronic family stress is associated with immune changes in children with asthma. *Psychosomatic Medicine*. 2009;71(4):378-384. http://www.ncbi.nlm.nih.gov/pubmed/19196805. doi: 10.1097/PSY.0b013e318199dbc3.
21. Fuertes E, Markevych I, Bowatte G, et al. Residential greenness is differentially associated with childhood allergic rhinitis and aeroallergen sensitization in seven birth cohorts. *Allergy*. 2016;71(10):1461-1471.
22. Andrusaityte S, Grazuleviciene R, Kudzyte J, Bernotiene A, Dedele A, Nieuwenhuijsen MJ. Associations between neighbourhood greenness and asthma in preschool children in Kaunas, Lithuania: A case-control study. *BMJ Open*. 2016;6(4):010341.
23. Weir LA, Etelson D, Brand DA. Parents' perceptions of neighborhood safety and children's physical activity. *Preventive Medicine*. 2006;43(3):212-217. doi: 10.1016/j.ypmed.2006.03.024.
24. Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: Evidence from a national longitudinal study. *American Journal of Epidemiology*. 2013:kws353.
25. Kanchongkittiphon W, Mendell MJ, Gaffin JM, Wang G, Phipatanakul W. Indoor environmental exposures and exacerbation of asthma: An update to the 2000 review

by the institute of medicine. . 2015;123(1):6. http://nrs.harvard.edu/urn-3:HUL.InstRepos:13890681.
26. Beck AF, Huang B, Ryan PH, Sandel MT, Chen C, Kahn RS. Areas with high rates of police-reported violent crime have higher rates of childhood asthma morbidity. *J Pediatr*. 2016;173:182.e1.
27. Butz AM, Bellin M, Tsoukleris M, et al. Very poorly controlled asthma in urban minority children: Lessons learned. *The Journal of Allergy and Clinical Immunology: In Practice*. 2018;6(3):844-852. https://www.sciencedirect.com/science/article/pii/S2213219817306177. doi: 10.1016/j.jaip.2017.08.007.
28. Jackson RD, Huete AR. Interpreting vegetation indices. *Preventive Veterinary Medicine*. 1991;11(3):185-200. http://www.sciencedirect.com/science/article/pii/S0167587705800042. doi: 10.1016/S0167-5877(05)80004-2.
29. ESRI. ArcGIS desktop: Release 10. 2010.
30. Dadvand P, de Nazelle A, Figueras F, et al. Green space, health inequality and pregnancy. *Environment International*. 2012;40:110-115. http://www.sciencedirect.com/science/article/pii/S0160412011001905. doi: 10.1016/j.envint.2011.07.004.
31. United States Department of Justice. Federal bureau of investigation: Uniform crime reporting statistics: UCR offense definitions. Updated 2016.
32. Sameroff A, Seifer R, Barocas R, Zax M, Greenspan S. Intelligence quotient scores of 4-year-old children: Social-environmental risk factors. *Pediatrics*. 1987;79(3):343-350.
33. Favaro P, Lam T, Durocher D. Social risk index-elementary and secondary schools. *Mississauga, Ontario: Peel District School Board, Assessment and Accountability-Curriculum, Instruction and Special Education Support Services.* 2008.
34. Cheng E, Poehlmann-Tynan J, Mullahy J, Witt W. Cumulative social risk exposure, infant birth weight, and cognitive delay in infancy. *Academic Pediatrics*. 2014;14(6):581588. https://search.proquest.com/docview/1627055529.
35. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*. 1977;1(3):385-401. http://journals.sagepub.com/doi/full/10.1177/014662167700100306. doi: 10.1177/014662167700100306.
36. Martinez ML, Black M, Starr RH. Factorial structure of the perceived neighborhood scale (PNS): A test of longitudinal invariance. *Journal of Community Psychology*. 2002;30(1):23-43. http://onlinelibrary.wiley.com/doi/10.1002/jcop.1048/abstract. doi: 10.1002/jcop.1048.
37. Benowitz NL. Cotinine as a biomarker of environmental tobacco smoke exposure. *Epidemiological Review*. 1996;18(2):188-204.
38. Butz A, Morphew T, Lewis-Land C, et al. Factors associated with poor controller medication use in children with high asthma emergency department utilization. *Annals of Allergy, Asthma & Immunology*. 2017;118 (4):419-426. doi: 10.1016/j.anai.2017.01.007.
39. Schatz M, Zeiger RS, Vollmer WM, et al. The controller-to-total asthma medication ratio is associated with patient-centered as well as utilization outcomes. *Chest*.

2006;130(1):43-50. https://www.sciencedirect.com/science/article/pii/S0012369215509513. doi: 10.1378/chest.130.1.43.
40. Johnson D, Young R. Towards best practices in analyzing datasets with missing data: Comparisons and recommendations. *Journal of Marriage and Family*. 2011;73(5):926-945.
41. White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine*. 2011;30(4):377-399. https://onlinelibrary.wiley.com/doi/abs/10.1002/sim.4067. doi: 10.1002/sim.4067.
42. Desai M, Kubo J, Esserman D, Terry MB. The handling of missing data in molecular epidemiology studies. *Cancer epidemiology, biomarkers & prevention : a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology*. 2011;20(8):1571-1579. https://www.ncbi.nlm.nih.gov/pubmed/21750174. doi: 10.1158/1055-9965.EPI-10-1311.
43. Markevych I, Schoierer J, Hartig T, et al. Exploring pathways linking greenspace to health. *Environmental Research*. 2017;158:301-317. https://www.narcis.nl/publication/RecordID/oai:library.wur.nl:wurpubs%2F524119.
44. StataCorp. Stata statistical software: Release 14. . 2015.
45. Homa DM, Neff LJ, King BA, et al. Vital signs: Disparities in nonsmokers' exposure to secondhand smoke--United States, 1999-2012. *MMWR. Morbidity and mortality weekly report*. 2015;64(4):103-108. https://www.ncbi.nlm.nih.gov/pubmed/25654612.
46. Feng X, Astell-Burt T. Is neighborhood green space protective against associations between child asthma, neighborhood traffic volume and perceived lack of area safety? multilevel analysis of 4447 Australian children. *International Journal of Environmental Research and Public Health*. 2017;14(5):543. https://search.proquest.com/docview/1910604872. doi: 10.3390/ijerph14050543.
47. Hazer M, Formica MK, Dieterlen S, Morley CP. The relationship between self-reported exposure to greenspace and human stress in Baltimore, MD. *Landscape and Urban Planning*. 2018;169:47-56. https://www.sciencedirect.com/science/article/pii/S0169204617301901. doi: 10.1016/j.landurbplan.2017.08.006.
48. Wolch JR, Byrne J, Newell JP. Urban green space, public health, and environmental justice: The challenge of making cities ‘just green enough’. *Landscape and Urban Planning*. 2014;125:234-244. https://www.sciencedirect.com/science/article/pii/S0169204614000310. doi: 10.1016/j.landurbplan.2014.01.017.
49. Koball H, Jiang Y. Basic facts about low-income children; children under 18 years, 2016. *National Center for Children in Poverty*. 2018.

CHAPTER 4: ADDENDUM

Results

Aim 2. Examine the association between neighborhood safety (measured as neighborhood violent crime rate and parent perception of neighborhood safety) and level of asthma control. Controlling for allergic sensitization, child asthma medication use, asthma triggers within the home (cockroaches, rats, mice and secondhand smoke), season of enrollment, child demographics, family income, and neighborhood social cohesion the second hypothesis is as follows: **H2B: Parent perception of an unsafe neighborhood will be associated with poor asthma control.**

Multiple regression was used to test the hypothesis that children living in unsafe neighborhoods would have poorer asthma control. In model 1 (Table 5) asthma medication ratio [AMR] was significantly associated with level of asthma control after adjusting for social risk, season, outdoor allergen sensitization, secondhand smoke exposure and perceived neighborhood unsafety (aOR 2.42; 95% CI [1.14, 5.13]). In this model, perceived neighborhood unsafety was not associated with level of asthma control. The final model (Model 2) included social risk, season, AMR, outdoor allergen sensitization, secondhand smoke exposure, perceived neighborhood unsafety, and an interaction between perceived neighborhood unsafety and secondhand smoke exposure. One covariate, AMR, was significantly associated with level of asthma control in this model (aOR 2.51; 95% CI [1.18, 5.33]). The interaction between perceived neighborhood unsafety and secondhand smoke exposure was not significant. The results do not support the hypothesis that for these children, living in unsafe neighborhoods is associated with poorer asthma control.

Table 5. Logistic Regression examining odds of Very Poorly Controlled (VPC) Asthma (n=160)

	Odds ratio (95% CI)		
Variable	Unadjusted relationships OR (95% CI)	Model 1 aOR (95% CI)	Model 2 Final Model aOR (95% CI)
Child age (6-12 years vs. Ref. 2-5 years)	1.14 (0.65, 2.01)		
Child sex (male)	1.25 (0.21, 7.68)		
Social Risk Index (SRI)	1.13 (0.93, 1.37)	1.15 (0.90, 1.48)	1.18 (0.91, 1.52)
Season @ Baseline: Fall	Ref	Ref	Ref
Winter	1.69 (0.81, 3.51)	1.20 (0.50, 2.87)	1.15 (0.48, 2.75)
Spring	0.92 (0.42, 2.02)	0.77 (0.31, 1.91)	0.72 (0.29, 1.83)
Summer	1.23 (0.54, 2.80)	0.95 (0.36, 2.53)	0.96 (0.36, 2.56)
Asthma Medication Ratio ≥0.50	2.20 (1.20, 4.05)*	2.42 (1.14, 5.13)*	2.51 (1.18, 5.33)*
Indoor Allergen Sensitization (yes)	0.60 (0.27, 1.36)		
Outdoor Allergen Sensitization (yes)	0.64 (0.35, 1.18)	0.52 (0.26, 1.04)	0.51 (0.25, 1.03)
Secondhand Smoke (SHS) (positive)	0.72 (0.39, 1.31)	0.55 (0.27, 1.13)	0.16 (0.02, 0.99)*
Perceived Neighborhood Unsafety	1.02 (0.99, 1.05)	1.02 (0.98, 1.06)	0.98 (0.92, 1.04)
Interactions			
SHS Exposure X Perceived Neighborhood Unsafety			1.06 (0.98, 1.14)

*p<0.05

H2C: Parent perception of neighborhood safety will be more strongly associated with level of asthma control than neighborhood violent crime rate.

Hypothesis 2C was not supported; violent crime victimization rate contributes more to explaining level of asthma control than perception of neighborhood safety, as determined by testing hypotheses 2A and 2B.

Conclusions

These analyses sought to understand the relationships between neighborhood safety and level of asthma control in a sample of children with asthma living in low-income urban communities. The results suggest that for this sample, there is no association between parent perception of neighborhood safety and level of asthma control and neighborhood violence is more strongly associated with level of asthma control than perception of safety.

This study did not find an association between parent perception of neighborhood safety and their child's level of asthma control. It is possible that measuring neighborhood safety using parent perceptions does not accurately translate into the child's perception of neighborhood safety. Additional analyses of this data (manuscript in development) found that parent perception of neighborhood safety is significantly associated with parent mental health outcomes, measured using the Centers for Epidemiological Studies Depression Scale, such that parents who perceived their neighborhoods as unsafe are more likely to report depressive symptoms. In this same study, neighborhood violence was not found to be associated with parent mental health outcomes. It might be that parent perception of neighborhood safety has strong associations to parent stress exposure but is too distal a measure of children's stress exposure. This would also explain why our data indicate that neighborhood violence contributes more to explaining level of asthma control, than parent perception of neighborhood safety. To test this theory, future research should measure children's perception of neighborhood safety as it relates to their level of asthma control.

CHAPTER 5: SYNTHESIS/DISCUSSION

Introduction

The goal of this research was to inform policies and practices for improving health outcomes for children with asthma living in urban poverty by understanding the role greenspace and neighborhood safety might play in asthma control. This study examined the relationships among neighborhood greenspace, neighborhood safety (based on neighborhood violent crime victimization rate and parents' perception of neighborhood safety) and level of asthma control in a sample of 196 African American children diagnosed with asthma from low-income neighborhoods in Baltimore City. This chapter presents a summary of the results presented by study aim. Findings are discussed for each study aim followed by the strengths and limitations of the study. This chapter concludes with the implications of the study's findings in regard to research and policy.

Summary of Findings

Aim 1: Examine the association between neighborhood greenspace and level of asthma control. H1: Controlling for allergic sensitization, child asthma medication use, asthma triggers within the home (cockroaches, rats, mice and secondhand smoke), season of enrollment, child demographics and family income, a higher index of neighborhood greenspace (measured as NDVI) will be associated with better asthma control (measured as not well controlled [NWC] asthma compared to the worse outcome measured as very poorly controlled [VPC] asthma).

A series of multiple regression models were used to test the first hypothesis that children living in areas with high neighborhood greenspace would have better asthma control compared to children living in areas with low neighborhood greenspace. The final model included social risk, season, asthma medication ratio (AMR), outdoor allergen sensitization, secondhand smoke exposure, greenspace, and an interaction between greenspace and secondhand smoke exposure. The interaction between greenspace and secondhand smoke exposure was statistically significant (p=0.002). To interpret this interaction, the sample was stratified by secondhand smoke exposure. Among children exposed to secondhand smoke (n=98), residing in a high greenspace neighborhood was associated with a lower likelihood of having VPC asthma (aOR= 0.39; 95% CI [0.15, 1.02]), but among children who were not exposed to secondhand smoke (n=69), residing in a high greenspace neighborhood was associated with a higher likelihood of having VPC asthma (aOR 2.43; 95% CI [0.78, 7.61]). While the stratified analyses were not statistically significant they are included to present the directions of associations between greenspace and asthma control. Overall, the first hypothesis was not supported but additional analyses indicate a significant interaction between secondhand smoke and greenspace.

Aim 2: Examine the association between neighborhood safety (measured as violent crime victimization rate and parent perception of neighborhood safety) and level of asthma control. Controlling for allergic sensitization, child asthma medication use, asthma triggers within the home (cockroaches, rats, mice and secondhand smoke), season of enrollment, child demographics, family income, and neighborhood social cohesion the hypotheses are as follows: H2A: Higher rates of violent crime victimization will be associated with poor asthma control. H2B: Parent perception of an unsafe neighborhood will be associated with poor asthma control. H2C: Parent perception of neighborhood safety will be more strongly associated with level of asthma control than violent crime victimization rate.

Multivariable logistic regression was used to test whether children living in neighborhoods with higher violence would have poorer asthma control compared to children living in neighborhoods with lower violence (H2A). The final model included social risk, season, AMR, outdoor allergen sensitization, secondhand smoke exposure, violence, and an interaction between violence and secondhand smoke exposure. The interaction between violence and secondhand smoke exposure was significant ($p=0.004$). To interpret this interaction, the sample was stratified by secondhand smoke exposure. Among children exposed to secondhand smoke ($n=98$), the likelihood of having VPC asthma increased for every point increase in neighborhood violence (aOR= 1.03; 95% CI [0.99, 1.08]). Among children not exposed to secondhand smoke ($n=69$), the likelihood of having VPC asthma decreased for every point increase in neighborhood violence (aOR 0.97; 95% CI [0.91, 1.04]). However, neither result was statistically significant.

Multiple regression was used to test the hypothesis that children living in unsafe neighborhoods would have poorer asthma control (H2B). In all models, perceived neighborhood unsafety was not associated with level of asthma control. The results do not support the hypothesis that for this sample, living in neighborhoods perceived to be unsafe is associated with poorer asthma control.

Hypothesis 2C was not supported; perception of neighborhood safety did not have a stronger association to level of asthma control than violent crime victimization rate.

Aim 3: **Explore neighborhood safety (violent crime victimization rate and parent perception of neighborhood safety) as a potential moderator in the**

association between neighborhood greenspace and level of asthma control. H3: Controlling for allergic sensitization, child asthma medication use, asthma triggers within the home (cockroaches, rats, mice and secondhand smoke), season of enrollment, child demographics, family income, and neighborhood social cohesion, neighborhood safety will moderate the relationship between greenspace and level of asthma control such that safer neighborhoods (relative to others in the sample) will strengthen the association between a higher index of greenspace and improved asthma control.

Based on the finding from aim 2 that parental perception of neighborhood safety was not associated with level of asthma control, subsequent analyses only used neighborhood violence to examine the impact of neighborhood safety on the relationship between neighborhood greenspace and level of asthma control.

To test the hypothesis that neighborhood violence modified the relationship between greenspace and level of asthma control (H3) an interaction term between violence and greenspace was added into a multivariable logistic regression model. In this model, violence was not found to moderate the relationship between greenspace and level of asthma control. Further analyses trichotomized violence based on the lowest, middle, and highest third of violent crime victimization rates to analyze for patterns in the effect size as opposed to analyzing for statistical significance. For children living in neighborhoods with the highest violent crime victimization rate, more greenspace was associated with a lower likelihood of having VPC asthma compared to children living in areas with low greenspace (OR 0.89; 95% CI [0.29, 2.73]). However, among children living in neighborhoods with the lowest violent crime rate, high neighborhood greenspace was associated with a greater likelihood of having VPC asthma (OR 2.29; 95% CI [0.58, 9.08]). For children living in neighborhoods in the middle strata of violent crime, those living in areas with high greenspace were less likely to have VPC asthma than those in areas with low greenspace (OR 0.62; 95% CI [0.23, 1.68]). Given the lack of a consistent pattern of relationships between neighborhood greenspace and asthma control found by level of neighborhood violent crime rate, the results do not support the third hypothesis that neighborhood violence would modify the relationship between greenspace and asthma control in this sample of children.

Limitations and Strengths

There are a number of study limitations that warrant consideration. Given that this study used a cross-sectional design, it is not possible to assume directionality to the associations between variables. It is possible that families moved to greener, less violent neighborhoods prior to enrollment in order to improve their children's asthma. For this sample, however, the median length of time children lived at their current address was two years and sensitivity analyses indicated similar results after controlling for length time in the neighborhood.

This study used an existing sample of children recruited for a larger study testing a home-based/environmental asthma intervention. Although a number of confounding variables were controlled for, there were others that were not included in the analyses because they had not been collected from the families. For example, including data on children's actual exposure to greenspace would have provided a more accurate picture of their true exposure. Also, including data on children's perception of neighborhood safety might have been a stronger measure of their stress exposure than parent perceptions. Neighborhood, defined in this study by census tract and buffer areas surrounding the child's home address, may not reflect how these families define their neighborhood nor does it account for time children spend with other family members who may live in a different geographic area. There can also be edge effects in that those living close to the edge of the census tract may perceive their neighborhood as encompassing more than one or several census tracts. Future research should ask parents and children about where they spend their time and how they define their neighborhoods, rather than using administrative boundaries to define neighborhoods. Another option might be to design a study incorporating wearable geographic information systems technology to get an idea of areas where children spend their time and the geography of their neighborhoods.

Another limitation of using existing data was the limited sample size. The power analysis demonstrated that the sample size was sufficient to test the hypothesis in aim 1, but the sample size was not adequate to test moderation. Therefore, future research should build on these preliminary findings using larger sample sizes in order to investigate potential moderation.

All of the children in this study had uncontrolled asthma, which may have limited our ability to detect differences between those with not well controlled and very poorly controlled asthma. The rationale for focusing on these two extreme groups of children was based on the fact that economically disadvantaged, African American children living with uncontrolled asthma experience the highest asthma burden and risk for asthma related death. However, this diminished variability between the two comparison groups may have biased results toward the null. Future studies should sample children with a wider range in level of asthma control.

Overall, this study did not demonstrate that more neighborhood greenspace is associated with better asthma control. While NDVI is an objective and validated measure of neighborhood greenspace, there are limitations to its use. NDVI measures quantity of green vegetation but it does not measure characteristics of greenspace that may make them healthier spaces for children. For example, NDVI does not distinguish between a vacant lot that is overgrown with weeds or a neighborhood park with a playground and benches that may encourage physical activity and psychological restoration, two pathways through which greenspace improves health. The null findings in this study could be due to the inability to measure these nuanced qualities of greenspace that may relate to specific mechanisms through which greenspace influences health. A recent study linking greenspace to reduced stress, presented a survey strategy that might be a stronger measure for greenspace exposure.[75] The survey asked individuals about both visual and physical exposure to greenspace in three areas: near the home; near their work or school; and during recreation; and the weekly duration of all exposures. This measure of greenspace would improve on the limitations of using NDVI and should be considered in future research.

This study highlights the complexities of relationships between neighborhood variables. While there are clearly proposed mechanisms through which greenspace and safety may influence children's asthma, these theories need further development to accommodate additional variables (e.g. secondhand smoke exposure) and interrelationships between variables (e.g. correlations between greenspace and safety). There is a large body of research demonstrating that greenspace disproportionately benefits predominantly white, affluent neighborhoods.[76] Greenspaces, along with violence, are not randomly located but reflect a larger neighborhood context. And therefore, these theories might also benefit from expanding their scope to broader determinants such as neighborhood racial characteristics and neighborhood level socioeconomic status.

Despite its limitations, this study had several strengths. This study was innovative in its use of multiple methods and informants (geocoding, neighborhood crime statistics, parent reports, and physiologic measures) to understand how neighborhood factors are linked to asthma control in a sample of children who are predominantly African American and low-income. By controlling for covariates such as allergen sensitizations, asthma medication use, secondhand smoke exposure, and season of enrollment, this research improved on previous research investigating the associations between greenspace and asthma control. This study also included neighborhood violence as a contextual factor that could modify the potential benefits of neighborhood greenspace for children with asthma. A novel finding from this study is the potential role that secondhand smoke exposure plays in modifying associations among neighborhood factors (greenspace and violence) and asthma control. This finding warrants further investigation in future research.

Implications: Research

The results from this study increase our understanding of the complex relationships among neighborhood greenspace, neighborhood safety, and children’s level of asthma control. Future research is needed to address identified limitations. In order to generalize results to a larger population the sample size and variability should be expanded to include children with a range of levels of asthma control, including those who are well controlled. Increased variability amongst the sample will deepen our insight into how greenspace influences all levels of asthma control. Future research should be longitudinal in order to examine the influences of neighborhood greenspace and neighborhood safety on children's asthma control. Using primary data, the design should include variables to capture children's exposure to greenspace and children's perceptions of neighborhood safety. This additional research would help to inform future interventions to achieve health equity and reduce the asthma burden for families living in urban poverty.

Implications: Policy

The findings from this research support continued investigation into the mechanisms through which social determinants affect children's health, especially for children growing up in poverty. Results from this study demonstrate that physical and social environments may be associated with children's level of asthma control. This information supports a "Health in All Policies" approach[77] (World Health Organization, 2013) where decision makers across all sectors (e.g. urban development and safety) collaborate with health professionals before implementing policies. Through this collaboration and performing health impact assessments, harmful health impacts are avoided. The Health in All Policies approach is rooted in the idea that policy in all sectors influences health and therefore should be considered carefully during policy development, before policy implementation.

Policies should continue to support funding for research into the social determinants of health and interventions focused on achieving health equity for marginalized populations. Greenspace is a modifiable neighborhood factor that might improve asthma control for children growing up in urban poverty. The results of this study demonstrate that relationships between neighborhood greenspace and children's asthma control may be influenced by additional factors, such as secondhand smoke exposure, and warrant further investigation into the potential health benefits of neighborhood greenspace. For whom might greenspace and other environmental interventions be most effective?

Further research into the mechanisms through which neighborhood environments influence children's asthma may support updates to clinical guidelines for asthma treatment. These updated guidelines could encourage primary care providers to screen for the social determinants that are negatively impacting health and refer families to resources to assist them. There are already programs available to assist with this work. Transition to Success, for example, was developed as an evidence-based, measurable system of care that both screens and responds to the social determinants of health.[78] This treatment model was developed as a direct response to treat the condition of poverty and has been proposed to assess and address the social determinants of health that lead to health problems experienced by children living in poverty.[79]

REFERENCES for Chapters 1, 2 (addendum), and 5

1. Nurmagambetov T, Kuwahara R, Garbe P. The economic burden of asthma in the United States, 2008–2013. *Annals of the American Thoracic Society*. 2018;15(3):348-356. https://search.proquest.com/docview/2021667795. doi: 10.1513/AnnalsATS.201703-259OC.
2. Zahran H, Bailey C, Damon S, Garbe P, Breysse P. Vital signs: Asthma in children - United States, 2001-2016. *US Department of Health and Human Services/Centers for Disease Control and Prevention*. 2018:149-155.
3. U.S. Department of Health and Human Services, Center for Disease Control and Prevention, National Center for Environmental Health. Behavioral risk factors surveillance systems- child and adults asthma callback survey data, 2006-2010. . 2015.
4. U.S. Department of Health and Human Services, National Heart, Lung, and Blood Institute. The national asthma education and prevention program. expert panel report 3 (EPR3): Guidelines for the diagnosis and management of asthma. . 2007.
5. Braido F. Failure in asthma control: Reasons and consequences. *Scientifica*. 2013;2013:1-15. https://doaj.org/article/dc21d4685d7145d79acf9e1e918f143c. doi: 10.1155/2013/549252.
6. Buonanno G, Marks GB, Morawska L. Health effects of daily airborne particle dose in children: Direct association between personal dose and respiratory health effects. *Environmental Pollution*. 2013;180:246-250. http://www.ncbi.nlm.nih.gov/pubmed/23792384. doi: 10.1016/j.envpol.2013.05.039.
7. Nishimura KK, Galanter JM, Roth LA, et al. Early-life air pollution and asthma risk in minority children. the GALA II and SAGE II studies. *Am J Respir Crit Care Med*. 2013;188(3):309-318.
8. Vieira SE, Stein RT, Ferraro AA, et al. Urban air pollutants are significant risk factors for asthma and pneumonia in children: The influence of location on the measurement of pollutants. *Arch Bronconeumol*. 2012;48(11):389-395.
9. Northridge J, Ramirez OF, Stingone JA, Claudio L. The role of housing type and housing quality in urban children with asthma. *J Urban Health*. 2010;87(2):211-224.
10. Olmedo O, Goldstein IF, Acosta L, et al. Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in New York City. *J Allergy Clin Immunol*. 2011;128(2):292.e7.
11. Butz AM, Breysse P, Rand C, et al. Household smoking behavior: Effects on indoor air quality and health of urban children with asthma. *Matern Child Health J*. 2011;15(4):460-468.
12. Coutinho MT, McQuaid EL, Koinis-Mitchell D. Contextual and cultural risks and their association with family asthma management in urban children. *J Child Health Care*. 2013;17(2):138-152.
13. Vangeepuram N, Galvez MP, Teitelbaum SL, Brenner B, Wolff MS. The association between parental perception of neighborhood safety and asthma diagnosis in ethnic minority urban children. *J Urban Health*. 2012;89(5):758-768.
14. Koinis-Mitchell D, Kopel SJ, Salcedo L, McCue C, McQuaid EL. Asthma indicators and neighborhood and family stressors related to urban living in children. *Am J Health Behav*. 2014;38(1):22-30.

15. Quinn KA. *An ecological examination of psychological stress and asthma among low-income families in Chicago: Family, housing and neighborhood determinants.* ProQuest Information & Learning; 2011.
16. Evans GW, Kim P. Childhood poverty, chronic stress, Self-Regulation, and coping. *Child Development Perspectives*. 2013;7(1):43-48. https://onlinelibrary.wiley.com/doi/abs/10.1111/cdep.12013. doi: 10.1111/cdep.12013.
17. US Environmental Protection Agency. What is open space/green space. https://www3.epa.gov/region1/eco/uep/openspace.html. Updated 2016.
18. Sbihi H, Tamburic L, Koehoorn M, Brauer M. Greenness and incident childhood asthma: A 10-year follow-up in a population-based birth cohort. *Am J Respir Crit Care Med*. 2015;192(9):1131-1133.
19. Kingsley J, Townsend M. 'Dig in' to social capital: Community gardens as mechanisms for growing urban social connectedness. *Urban Policy and Research*. 2006;24(4):525-537. http://www.tandfonline.com/doi/abs/10.1080/08111140601035200. doi: 10.1080/08111140601035200.
20. Yamaguchi M, Deguchi M, Miyazaki Y. The effects of exercise in forest and urban environments on sympathetic nervous activity of normal young adults. *The Journal of International Medical Research*. 2006;34(2):152-159. http://www.ingentaconnect.com/content/field/jimr/2006/00000034/00000002/art00004. doi: 10.1177/147323000603400204.
21. Hansmann R, Hug S, Seeland K. Restoration and stress relief through physical activities in forests and parks. *Urban Forestry & Urban Greening*. 2007;6(4):213-225. http://www.sciencedirect.com/science/article/pii/S1618866707000623. doi: 10.1016/j.ufug.2007.08.004.
22. Irvine KN, Warber SL, Devine-Wright P, Gaston KJ. Understanding urban green space as a health resource: A qualitative comparison of visit motivation and derived effects among park users in Sheffield, UK. *International journal of environmental research and public health*. 2013;10(1):417-442. http://www.ncbi.nlm.nih.gov/pubmed/23340602. doi: 10.3390/ijerph10010417.
23. Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A. *Environmental health : a global access science source*. 2016;15(1):57. http://www.ncbi.nlm.nih.gov/pubmed/27117324. doi: 10.1186/s12940-016-0142-z.
24. Tosca MA, Ruffoni S, Canonica GW, Ciprandi G. Asthma exacerbation in children: Relationship among pollens, weather, and air pollution. *Allergologia et Immunopathologia*. 2014;42(4):362-368. http://www.ncbi.nlm.nih.gov/pubmed/23755880. doi: 10.1016/j.aller.2013.02.006.
25. Esposito S, Galeone C, Lelii M, et al. Impact of air pollution on respiratory diseases in children with recurrent wheezing or asthma. *BMC Pulmonary Medicine*. 2014;14(1):130. http://www.ncbi.nlm.nih.gov/pubmed/25098250. doi: 10.1186/1471-2466-14-130.
26. Marin TJ, Chen E, Munch JA, Miller GE. Double-exposure to acute stress and chronic family stress is associated with immune changes in children with asthma.

Psychosomatic Medicine. 2009;71(4):378-384. http://www.ncbi.nlm.nih.gov/pubmed/19196805. doi: 10.1097/PSY.0b013e318199dbc3.
27. Sbihi H, Tamburic L, Koehoorn M, Brauer M. Greenness and incident childhood asthma: A 10-year follow-up in a population-based birth cohort. *Am J Respir Crit Care Med*. 2015;192(9):1131-1133.
28. Fuertes E, Markevych I, Bowatte G, et al. Residential greenness is differentially associated with childhood allergic rhinitis and aeroallergen sensitization in seven birth cohorts. *Allergy*. 2016;71(10):1461-1471. http://www.narcis.nl/publication/RecordID/oai:pure.rug.nl:publications%2Fcbf46b97-28f0-46e7-a880-afc0c37260d8. doi: 10.1111/all.12915.
29. Andrusaityte S, Grazuleviciene R, Kudzyte J, Bernotiene A, Dedele A, Nieuwenhuijsen MJ. Associations between neighbourhood greenness and asthma in preschool children in Kaunas, Lithuania: A case-control study. *BMJ open*. 2016;6(4):e010341. http://www.ncbi.nlm.nih.gov/pubmed/27067890. doi: 10.1136/bmjopen-2015-010341.
30. Dadvand P, Villanueva CM, Font-Ribera L, et al. Risks and benefits of green spaces for children: A cross-sectional study of associations with sedentary behavior, obesity, asthma, and allergy. *Environ Health Perspect*. 2014;122(12):1329-1335.
31. Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: Evidence from a national longitudinal study. *American Journal of Epidemiology*. 2013:kws353.
32. Kanchongkittiphon W, Mendell MJ, Gaffin JM, Wang G, Phipatanakul W. Indoor environmental exposures and exacerbation of asthma: An update to the 2000 review by the Institute of Medicine. . 2015;123(1):6. http://nrs.harvard.edu/urn-3:HUL.InstRepos:13890681.
33. Beck AF, Huang B, Ryan PH, Sandel MT, Chen C, Kahn RS. Areas with high rates of police-reported violent crime have higher rates of childhood asthma morbidity. *The Journal of Pediatrics*. 2016;173:182.e1. http://www.sciencedirect.com/science/article/pii/S0022347616001669. doi: 10.1016/j.jpeds.2016.02.018.
34. Butz AM, Ogborn J, Mudd S, et al. Factors associated with high short-acting β2-agonist use in urban children with asthma. *Annals of allergy, asthma & immunology : official publication of the American College of Allergy, Asthma, & Immunology*. 2015;114(5):385-392. http://www.ncbi.nlm.nih.gov/pubmed/25840499. doi: 10.1016/j.anai.2015.03.002.
35. Akinbami LJ, Moorman JE, Bailey C, et al. Trends in asthma prevalence, health care use, and mortality in the United States, 2001-2010. *NCHS data brief*. 2012(94):1. http://www.ncbi.nlm.nih.gov/pubmed/22617340.
36. Grainge CL, Lau LCK, Ward JA, et al. Effect of bronchoconstriction on airway remodeling in asthma. *The New England Journal of Medicine*. 2011;364(21):2006-2015. http://www.ncbi.nlm.nih.gov/pubmed/21612469. doi: 10.1056/NEJMoa1014350.
37. McGeachie MJ, Dahlin A, Qiu W, et al. The metabolomics of asthma control: A promising link between genetics and disease. *Immunity, Inflammation and Disease*. 2015;3(3):224-238. doi: 10.1002/iid3.61.

38. Meyers, D. A. Bleecker, E.R., Holloway JW, Holgate ST. The genetics of asthma: Towards a personalized approach to diagnosis and treatment. *The Lancet. Respiratory Medicine*. 2014;2(5):405.
39. Forno E, Celedón J. Asthma and ethnic minorities: Socioeconomic status and beyond. *Current Opinion in Allergy and Clinical Immunology*. 2009;9(2):154-160. http://www.ncbi.nlm.nih.gov/pubmed/19326508. doi: 10.1097/ACI.0b013e3283292207.
40. Butz AM, Kub J, Bellin MH, Frick KD. Challenges in providing preventive care to inner-city children with asthma. *The Nursing clinics of North America*. 2013;48(2):241-257. http://www.ncbi.nlm.nih.gov/pubmed/23659811. doi: 10.1016/j.cnur.2013.01.008.
41. United States Environmental Protection Agency. Asthma research. . Updated 2016.
42. United States Department of Health and Human Services. Healthy people 2020: Respiratory diseases. . Updated 2016.
43. United States Department of Health and Human Services. The NIH almanac: National institute of nursing research. . Updated 2016.
44. Markevych I, Schoierer J, Hartig T, et al. Exploring pathways linking greenspace to health. *Environmental Research*. 2017;158:301-317. https://www.narcis.nl/publication/RecordID/oai:library.wur.nl:wurpubs%2F524119.
45. Lovasi GS, O'Neil-Dunne JPM, Lu JWT, et al. Urban tree canopy and asthma, wheeze, rhinitis, and allergic sensitization to tree pollen in a New York City birth cohort. *Environ Health Perspect*. 2013;121(4):494-500.
46. Chen E, Miller GE, Shalowitz MU, et al. Difficult family relationships, residential greenspace, and childhood asthma. *Pediatrics*. 2017;139(4):1-10.
47. Pilat MA, McFarland A, Snelgrove A, Collins K, Waliczek TM, Zajicek J. The effect of tree cover and vegetation on incidence of childhood asthma in metropolitan statistical areas of Texas
. *Horticultural Technology*. 2012;5(22):631-637.
48. Lovasi GS, Quinn JW, Neckerman KM, Perzanowski MS, Rundle A. Children living in areas with more street trees have lower prevalence of asthma. *J Epidemiol Community Health*. 2008;62(7):647-649.
49. Rhew IC, Vander Stoep A, Kearney A, Smith NL, Dunbar MD. Validation of the normalized difference vegetation index as a measure of neighborhood greenness. *Annals of Epidemiology*. 2011;21(12):946-952. https://www.sciencedirect.com/science/article/pii/S104727971100250X. doi: 10.1016/j.annepidem.2011.09.001.
50. Janusek LW, Tell D, Fishe K, Gaylord-Harden N, Mathews H. Influence of childhood adversity and neighborhood violence on inflammatory risk in young urban African American men. *Brain, Behavior, and Immunity*. 2012;26:S34. doi: 10.1016/j.bbi.2012.07.144.
51. Chen E, Strunk RC, Bacharier LB, Chan M, Miller GE. Socioeconomic status associated with exhaled nitric oxide responses to acute stress in children with asthma. *Brain Behavior and Immunity*. 2010;24(3):444-450. http://www.sciencedirect.com/science/article/pii/S0889159109005285. doi: 10.1016/j.bbi.2009.11.017.

52. Rosenberg SL, Miller GE, Brehm JM, Celedón JC. Stress and asthma: Novel insights on genetic, epigenetic, and immunologic mechanisms. *Journal of Allergy and Clinical Immunology*. 2014;134(5):1009-1015. http://www.ncbi.nlm.nih.gov/pubmed/25129683. doi: 10.1016/j.jaci.2014.07.005.
53. Gupta RS, Zhang X, Springston EE, et al. The association between community crime and childhood asthma prevalence in Chicago. *Annals of Allergy, Asthma & Immunology*. 2010;104(4):299-306. http://www.sciencedirect.com/science/article/pii/S1081120609000507. doi: 10.1016/j.anai.2009.11.047.
54. DePriest K, Butz A, Thorpe RJ. The relationship between neighborhood safety and children's asthma: An integrative review. *Journal of Pediatric Health Care*. 2018;32(6):600-611. https://www.sciencedirect.com/science/article/pii/S0891524518300774. doi: 10.1016/j.pedhc.2018.05.005.
55. Goldman-Mellor S, Margerison-Zilko C, Allen K, Cerda M. Perceived and objectively-measured neighborhood violence and adolescent psychological distress. *J Urban Health*. 2016;93(5):758-769. https://search.proquest.com/docview/1826089970. doi: 10.1007/s11524-016-0079-0.
56. Kimes D, Ullah A, Levine E, et al. Relationships between pediatric asthma and socioeconomic/urban variables in Baltimore, Maryland. *Health and Place*. 2004;10(2):141-152. http://www.sciencedirect.com/science/article/pii/S1353829203000546. doi: 10.1016/S1353-8292(03)00054-6.
57. Carver A, Timperio A, Crawford D. Playing it safe: The influence of neighbourhood safety on children's physical activity—A review. *Health and Place*. 2008;14(2):217-227. http://www.sciencedirect.com/science/article/pii/S1353829207000536. doi: 10.1016/j.healthplace.2007.06.004.
58. Wright RJ, Subramanian SV. Advancing a multilevel framework for epidemiologic research on asthma disparities. *CHEST Journal*. 2007;132(5 Suppl):769S. http://journal.publications.chestnet.org/content/132/5_suppl/757S.abstract. doi: 10.1378/chest.07-1904.
59. Kopel LS, Gaffin JM, Ozonoff A, et al. Perceived neighborhood safety and asthma morbidity in the school inner-city asthma study. *Pediatric Pulmonology*. 2015;50(1):17-24. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4096619/. doi: 10.1002/ppul.22986.
60. Sternthal MJ, Jun H, Earls F, Wright RJ. Community violence and urban childhood asthma: A multilevel analysis. *The European respiratory journal*. 2010;36(6):1400-1409. http://www.ncbi.nlm.nih.gov/pubmed/20413538. doi: 10.1183/09031936.00003010.
61. Kuo M. How might contact with nature promote human health? promising mechanisms and a possible central pathway. *Frontiers in Psychology*. 2015;6. https://www.openaire.eu/search/publication?articleId=dedup_wf_001::9779812236a0c7d81ff7ae42aa01da43. doi: 10.3389/fpsyg.2015.01093.
62. Wright RJ, Mitchell H, Visness CM, et al. Community violence and asthma morbidity: The inner-city asthma study. *American Journal of Public Health*.

2004;94(4):625-632. http://ajph.aphapublications.org/cgi/content/abstract/94/4/625. doi: 10.2105/AJPH.94.4.625.
63. Kopel LS, Gaffin JM, Ozonoff A, et al. Perceived neighborhood safety and asthma morbidity in the school inner-city asthma study. *Pediatr Pulmonol*. 2015;50(1):17-24.
64. Sternthal MJ, Jun HJ, Earls F, Wright RJ. Community violence and urban childhood asthma: A multilevel analysis. *Eur Respir J*. 2010;36(6):1400-1409.
65. Chiu YM, Coull BA, Sternthal MJ, et al. Effects of prenatal community violence and ambient air pollution on childhood wheeze in an urban population. *The Journal of Allergy and Clinical Immunology*. 2014;133(3):22.e4. http://repository.cmu.edu/psychology/1260.
66. Baltimore City Department of Planning. City of Baltimore: Green network plan. . Updated 2016.
67. Nowak DJ, Crane DE, Stevens JC. Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry & Urban Greening*. 2006;4(3):115-123. http://www.sciencedirect.com/science/article/pii/S1618866706000173. doi: 10.1016/j.ufug.2006.01.007.
68. Roemmich JN, Epstein LH, Raja S, Yin L, Robinson J, Winiewicz D. Association of access to parks and recreational facilities with the physical activity of young children. *Preventive Medicine*. 2006;43(6):437-441. http://www.sciencedirect.com/science/article/pii/S0091743506002829. doi: 10.1016/j.ypmed.2006.07.007.
69. Fanelli A, Cabral ALB, Neder JA, Martins MA, Carvalho CRF. Exercise training on disease control and quality of life in asthmatic children. *Medicine and science in sports and exercise*. 2007;39(9):1474-1480. http://www.ncbi.nlm.nih.gov/pubmed/17805077. doi: 10.1249/mss.0b013e3180d099ad.
70. Marin TJ, Chen E, Munch JA, Miller GE. Double-exposure to acute stress and chronic family stress is associated with immune changes in children with asthma. *Psychosomatic Medicine*. 2009;71(4):378-384. http://www.ncbi.nlm.nih.gov/pubmed/19196805. doi: 10.1097/PSY.0b013e318199dbc3.
71. Chen E, Hanson MD, Paterson LQ, Griffin MJ, Walker HA, Miller GE. Socioeconomic status and inflammatory processes in childhood asthma: The role of psychological stress. *The Journal of Allergy and Clinical Immunology*. 2006;117(5):1014-1020. http://www.sciencedirect.com/science/article/pii/S0091674906002909. doi: 10.1016/j.jaci.2006.01.036.
72. Dadvand P, Villanueva CM, Font-Ribera L, et al. Risks and benefits of green spaces for children: A cross-sectional study of associations with sedentary behavior, obesity, asthma, and allergy. *Environ Health Perspect*. 2014;122(12):1329-1335.
73. Feng X, Astell-Burt T. Is neighborhood green space protective against associations between child asthma, neighborhood traffic volume and perceived lack of area safety? multilevel analysis of 4447 Australian children. *International Journal of Environmental Research and Public Health*. 2017;14(5):543. https://search.proquest.com/docview/1910604872. doi: 10.3390/ijerph14050543.

74. Quinto KB, Zuraw BL, Poon KT, Chen W, Schatz M, Christiansen SC. The association of obesity and asthma severity and control in children. *The Journal of Allergy and Clinical Immunology*. 2011;128(5):964-969. http://www.sciencedirect.com/science/article/pii/S0091674911010037. doi: 10.1016/j.jaci.2011.06.031.
75. Hazer M, Formica MK, Dieterlen S, Morley CP. The relationship between self-reported exposure to greenspace and human stress in Baltimore, MD. *Landscape and Urban Planning*. 2018;169:47-56. https://www.sciencedirect.com/science/article/pii/S0169204617301901. doi: 10.1016/j.landurbplan.2017.08.006.

76. Wolch JR, Byrne J, Newell JP. Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban Planning*. 2014;125:234-244. https://www.sciencedirect.com/science/article/pii/S0169204614000310. doi: 10.1016/j.landurbplan.2014.01.017
77. World Health Organization. Framework and statement: Consultation on the drafts of the "health in all policies framework for country action.". *8th Global Conference in Health Promotion*. 2013.
78. Wilson, M. Diagnosis: Poverty: A new approach for understanding and treating an epidemic. Highlands, TX: aha!Process, Inc. 2017.
79. Francis, L., DePriest, K., Wilson, M., & Gross, D. Child Poverty, Toxic Stress, and Optimizing the Nurses' Role in Screening and Addressing Social Determinants of Health in the Clinical Setting. *The Online Journal of Issues in Nursing.* 2018

Curriculum Vitae

Part I

PERSONAL DATA

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EDUCATION

Year	Degree	Institution	Location
2015-Present	PhD: Expected 05/2019	Johns Hopkins University School of Nursing	Baltimore, MD
2012-2013	BS	Johns Hopkins University School of Nursing	Baltimore, MD
2004-2008	BA	Colorado State University	Fort Collins, CO

CURRENT LICENSE AND CERTIFICATION

Year	Source	Type	License & Certification Number
2013-present	State of Maryland	RN	R207633

PROFESSIONAL EXPERIENCE

Year	Position	Institution	Location
2018	Clinical Instructor Public Health	Johns Hopkins University School of Nursing	Baltimore, MD
2017	Teaching Assistant Population Health	Johns Hopkins University School of Nursing	Baltimore, MD
2016-2017	Clinical Instructor Child Health	Johns Hopkins University School of Nursing	Baltimore, MD
2016	Teaching Assistant Child Health	Johns Hopkins University School of Nursing	Baltimore, MD
2013- 2017	Nurse Clinician: PICU	Johns Hopkins Hospital	Baltimore, MD
2008-2011	Peace Corps Volunteer	United States Peace Corps	Saint Lucia

HONORS AND AWARDS

2018-2020 Selected American Academy of Nursing Jonas Policy Scholar

2017 Second Place, 3 Minute Thesis Competition, Johns Hopkins University

2016 Scholl Foundation Fellowship, School of Nursing, Johns Hopkins University

2016 Winner, Graduate Nursing Student Academy "My 2020 Vision for Nursing" Video Contest

2013 Inducted into Sigma Theta Tau International: Nu Beta Chapter, School of Nursing, Johns Hopkins University

2012-2013 Recipient of the John & Ruth Ward Gurtler Foundation Scholarship, School of Nursing, Johns Hopkins University

2006-2008 Phi Kappa Phi, Honor Society, Colorado State University

2005-2008 Alpha Kappa Delta (Sociological Honor Society) member, Colorado State University

2005-2008 Dean's List: Colorado State University

RESEARCH

Sponsored Projects

2017-2019 Investigating the Relationships among Neighborhood Factors and Asthma Control in African American Children (Principal Investigator: Kelli DePriest, Primary Sponsor: Deborah Gross) F31NR017319-01 National Institute of Nursing Research, NIH

2017-2018 Pre-doctoral Clinical Research Training Program (PI: Ford, D), Research Fellow, NIH-5TL1TR001078-05 (award returned when NIH grant funded)

2010-2011 Volunteer Activities Support and Training (VAST) Grant to support implementation and evaluation research of HIV/AIDS and Life skills training program (Football for Lives) for 5th and 6th grade children and educators in partnership with *Grassroots Soccer.* Saint Lucia, Eastern Caribbean

Unsponsored Research Projects

2018-Present Qualitative interview coding and analyses- Community Based study on Home Visiting Engagement. PI: Dr. Kelly Bower, Research Assistant

2016-Present Consenting parents, conducting qualitative interviews, entering data, analyzing qualitative and quantitative data, disseminating results- Asthma Express: An NIH-funded study testing the efficacy of a home-based intervention on improving asthma control in a sample of children with persistent asthma. PI: Dr. Arlene Butz (NINR/NIH, #R01 NR013486), Research Assistant

2016-2017 Recruitment- Chicago Parenting Program: Implementation in Baltimore City Schools. PI: Dr. Deborah Gross, Research Assistant.

SCHOLARSHIP

Publications

Peer-Reviewed (*data-based)

1. *Alhusen, J. L., Ayres, L., & **DePriest, K**. (2016). Effects of maternal mental health on engagement in favorable health practices during pregnancy. *Journal of Midwifery & Women's Health,* 61(2), 210-216, doi:10.1111/jmwh.12407.

2. **DePriest, K.** & Butz, A. (2017). Neighborhood-level factors related to asthma in children living in urban areas: an integrative literature review. *The Journal of School Nursing,* 33(1), 8-17, doi:10.1 177/1059840516674054.

3. **DePriest, K.**, Butz, A., & Thorpe, R. (2018). The relationship between neighborhood safety and children's asthma: An integrative review. *Journal of Pediatric Health Care,* 32(6). 600-611, doi:10.1016/j.pedhc.2018.05.005.

4. **DePriest, K**., Butz, A., & Gross, D. (2018). Investigating the relationships among neighborhood factors and asthma control in African American children: A study protocol. *Research in Nursing and Health,* 41(5), 428-439, doi:10.1002/nur.21901.

5. Francis, L., **DePriest, K**., Wilson, M., & Gross, D. (2018) Child Poverty, Toxic Stress, and Social Determinants of Health: Screening and Care Coordination. *OJIN: The Online Journal of Issues in Nursing,* 23(3), doi:10.3912/OJIN.Vol23No03Man02.

6. *Butz, A., Bollinger, M., Ogborn, J., Morphew, T., Mudd, S., Kub, J., Bellin, M., Lewis-Land, C., **DePriest, K.,** & Tsoukleris, M. (2019). Children with poorly controlled asthma: Randomized controlled trial of a home-based environmental control intervention. *Pediatric Pulmonology,* 1-12, doi:10.1002/ppul.24239.

7. Veenema, T., Rush, Z., **DePriest, K**., & McCauley, L. (accepted) Climate change-related hurricane impact on Puerto Rico and the US Virgin Islands, environment risk reduction, and the social determinants of health. *Nursing Economics*.

Non-peer Reviewed

1. DePriest, K. (2017). Health Equity: The Power of Green Space. *On the Pulse Blog.* Johns Hopkins School of Nursing. https://magazine.nursing.jhu.edu/2017/09/health-equity-power-green-space/

PRESENTATIONS

International

1. **DePriest, K**., Butz, A., Land, C., & Bollinger, M. Access to greenspace and asthma symptoms in urban children with persistent asthma. Poster Presentation. European Respiratory Society International Congress. September 11th, 2017. Milan, Italy.

National

1. **DePriest, K**., Tsoukleris, M., Land, C., & Butz, A. Use of Home Remedies in urban children with persistent asthma. Poster Presentation. American Public Health Association Annual Meeting. November 1, 2016. Denver, CO.

2. **DePriest, K**., Butz, A., Kub, J., Lewis-Land, C., & Curriero, F. Could increasing greenspace in urban neighborhoods decrease asthma symptoms for children exposed to secondhand smoke (SHS)? Oral Presentation. American Public Health Association Annual Meeting. November 12, 2018. San Diego, CA.

EDITORIAL ACTIVITIES

Peer Review Activities

2018	Manuscript Reviewer, *The Journal for Nurse Practitioners*
2018-present	Manuscript Reviewer, *Journal of Urban Health*
2017-present	Manuscript Reviewer, *Journal of School Nursing*
2018-2019	Manuscript Reviewer, *Quality Management in HealthCare*
2018	Abstract Reviewer, American Public Health Association Annual Meeting, Public Health Nursing section
2017	Manuscript Review with Dr. Marie Nolan, *Advances in Nursing Doctoral Education and Research*
2016	Manuscript Review with Dr. Deborah Gross, *Research in Nursing and Health*

PROFESSIONAL ACTIVITIES

Society/Association Membership and Leadership

2018-2020	Selected Jonas Policy Scholar, American Academy of Nursing Jonas Policy Scholars Program
2018-Present	Communications Chair, American Public Health Association (APHA), Public Health Nursing Section
2017-Present	Web Editor, American Public Health Association (APHA), Public Health Nursing section
2013-Present	Member, Sigma Theta Tau International, Nu Beta (STTI)
2017-2018	Ethics Chair, Johns Hopkins University School of Nursing PhD Student Organization
2017-2018	Member, European Respiratory Society (ERS)
2016- 2017	Member, American Public Health Association (APHA), Public Health Nursing section
2015- 2016	Member, American Association of Critical-Care Nurses (AACN)

CURRICULUM VITAE
Part II

EDUCATIONAL ACTIVITIES

Fall 2018	**Public Health Nursing**, JHUSON, Clinical Instructor, 2 Credits, Masters Entry into nursing program, 8 students.
Spring 2018	**Public Health Nursing**, JHUSON, Clinical Instructor, 2 Credits, Masters Entry into nursing program, 6 students.
Fall 2017	**Facilitator** for Inter-professional Education Event with 9 students from the Notre Dame School of Pharmacy, Johns Hopkins Schools of Medicine and Nursing
Fall 2017	**Population Health Leadership** (NRSG 120.519), Johns Hopkins University School of Nursing, Teaching assistant, 2 Credits, Masters Entry in nursing program, 58 students
Summer 2017	**3 Day Teaching Institute,** Johns Hopkins University Center for Integration of Research, Teaching and Learning (CIRTL) Teaching Academy
2017-present	**Child Health** (NR.120.521.0201, NR.120.521.0101), JHUSON, Guest Lecturer, Masters Entry into nursing program
Spring 2017	**Child Health**, JHUSON, Clinical instructor, 2 Credits, Masters Entry into nursing program 11 students
Fall 2016	**Child Health,** JHUSON, Clinical instructor, 2 Credits, Masters Entry into nursing program, 6 students
Fall 2016	**Child Health** (NR.120.521.0201), JHUSON, Teaching assistant, 2 Credits, Masters Entry into nursing program, 105 students.
Spring 2008	**Ethnicity and the Media** (Colorado State University), Teaching assistant, 3 Credits, Bachelors level, 60 students.